Agricultural Development in BRAZIL

A CASE STUDY OF SAO PAULO

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ABSTRACT

Sao Paulo, Brazil's leading agricultural State, accounts for about 20 percent of Brazilian agricultural production. On an upward trend since 1950, Sao Paulo's agriculture is characterized by increased farmland, bigger yields, changing crops, and greater worker productivity. Major factors contributing to increased output are mechanization, government programs, and greater use of chemical fertilizers, pesticides, and improved seeds.

In particular, Sao Paulo leads Brazil in crop yields and labor productivity. Not only are yields in Sao Paulo higher than or equal to those in the rest of Brazil for most major commodities, but they also have been increasing at a faster rate. Sao Paulo's farm labor productivity is about twice as high as elsewhere in the country. For example, in 1970, Sao Paulo had 42 percent of Brazil's farm tractors, with 23 farmworkers per tractor, compared with 117 for all of Brazil.

Key words: Brazil, Agriculture, Crops, Livestock, Resources, Labor, Mechanization, Yields, Inputs, Land use.

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Note: Central refers to Center-West, Southeast, plus State of Parana.
Center-South refers to Center-West, Southeast and South.
Extreme South refers to the States of Santa Catarina and Rio Grande do Sul.

SUMMARY

Sao Paulo, with its long-term upward trend in agriculture, is Brazil's leading agricultural State. Although covering less than 3 percent of Brazil's land area and less than 10 percent of the crop and pasture area, the State accounts for about 20 percent of Brazilian agricultural production. Sao Paulo is Brazil's largest producer of sugarcane, cotton, peanuts, oranges, eggs, and poultry, and second ranking in coffee, corn, bananas, and milk.

Total farmland in Sao Paulo has increased somewhat since 1950, and an increasing proportion of farmland is being used for crops and pasture, from 68 percent in 1950 to 80 percent in 1970. Cropland increased little between 1950 and 1970, but pastureland increased 36 percent.

During 1950-70, substantial changes occurred in cropland allocation. Land devoted to coffee and cotton declined sharply, while area in most other major crops--particularly corn, peanuts, sugarcane, and oranges--increased. (Since 1970, soybeans have emerged as a major crop.) Most of the increases in corn and peanut area came, respectively, from land previously not cropped and land in cotton. Increases in sugarcane area came from lands formerly in coffee or pasture or lands not in crops. The growth in pastureland came from acreage taken out of coffee or unutilized land.

The 1950-70 changes in cropland allocation in Sao Paulo were due to the National Government's coffee diversification policy, changes in demand (as registered by changes in relative prices), changes in Sao Paulo's comparative advantages relative to other States, and a gradual shift to less labor-intensive crops due to policies which favored the purchase of machinery and raised the cost of onfarm labor.

Crop yields in Sao Paulo tended to increase gradually over 1950-73. One study estimated the annual rate of yield increase at 0.8 percent between 1947 and 1965. Between 1950-54 and 1969-73, cotton and coffee made the most spectacular growth in yields, due in great part to the elimination of production in low-yield areas. Corn, soybeans, oranges, sugarcane, and peanuts, however, all managed to register a modest upward trend in yields, while expanding area. Rice yields declined as production shifted to less desirable lands.

Crop yields in Sao Paulo are higher than or equal to those in the rest of Brazil for most major commodities. Only for rice and bananas are they lower. For corn, cotton, sugarcane, manioc, and tomatoes, yields are 20 to 50 percent higher than in Brazil as a whole. In addition, crop yields in Sao Paulo have been increasing at a faster rate than in the rest of Brazil.

Major factors responsible for the yield increases are increased use of chemical fertilizers, pesticides, and improved seeds. Consumption of fertilizer elements in Sao Paulo increased from 82,000 tons in 1954 to 680,000 tons in 1973. The rapid growth in fertilizer consumption was due, particularly in the late 1960's, to a decline in real fertilizer prices and the increased availability of low-cost credit for purchasing fertilizers and other "modern" inputs. Pesticide use approximately doubled between the mid-1950's and the mid-1960's, with the greatest share going to cotton. Improved varieties of cotton and corn contributed to increased yields of these commodities, although the full potential of hybrid corn varieties has not been realized, apparently because of insufficient fertilization.

In 1969, hybrid corn was planted in 78 percent of the corn area (compared with 30 percent in 1960), while all cotton area was planted with improved seed.

Sao Paulo's employed agricultural labor force declined from 1.7 million in 1960 to 1.5 million in 1970, while farm output per worker increased at an estimated rate of 2.5 percent per year during the 1960's. This increased output was made possible by a rapid increase in farm mechanization in Sao Paulo. For example, the number of tractors on farms increased from 28,000 in 1960 to 66,000 in 1970.

Farm labor productivity in Sao Paulo is about twice as high as elsewhere in the country. In 1970, Sao Paulo had 42 percent of Brazil's farm tractors, with 23 farmworkers per tractor, compared with 117 for all of Brazil. Also, Sao Paulo farmers consumed over one-third of the fertilizer used in Brazil in the early 1970's, and improved seeds are used more widely than in the rest of the country.

Sao Paulo's physical resources have undoubtedly been an important factor in its agricultural development. The soils, over one-third of them classed as good to excellent, are among the best in Brazil. Rainfall is adequate in all areas, and the topography does not inhibit mechanization in the principal agricultural regions. The quality of Sao Paulo's resources is shown by the high level of land use. In 1960, 59 percent of the State's land area was in crops and pasture, compared with 18 percent for all of Brazil. Only Rio Grande do Sul, with its extensive areas of natural pasture, had a higher land use ratio.

Aside from Sao Paulo's natural physical resources, most of the factors that have led to the relatively high level of agricultural development in Sao Paulo are transferable to the rest of Brazil. Education, research, extension services, more and improved highways, and storage facilities are all being developed at a rapid pace throughout the country. Even Sao Paulo's cultural traditions are being spread by the emigration of Sao Paulo farmers to Parana, Mato Grosso, Goias, Minas Gerais, and the Amazon Basin.

AGRICULTURAL DEVELOPMENT IN BRAZIL

A Case Study of Sao Paulo

Edmond Missiaen and Samuel O. Ruff[1]

INTRODUCTION

Procedure

Sao Paulo is Brazil's most important and best developed agricultural State. 2/ This study, concerned primarily with field crop production in Sao Paulo, examines the factors associated with the growth in the State's crop production. Trends in production are analyzed, as well as trends in the utilization of land, labor, and yield-improving inputs.

Agricultural technology in Sao Paulo is more advanced than in other Brazilian States for the production of most commodities. Comparing the circumstances associated with Sao Paulo's agricultural development with the rest of Brazil may give some indication of the entire country's progress in achieving its productive potential.

Whenever possible, statistics published by the Agricultural Economics Institute (Instituto de Economia Agricola or IEA) of the Sao Paulo Secretariat of Agriculture were used. However, when Sao Paulo is compared with other parts of Brazil, or when statistics for all of Brazil are required, data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatistica, or IBGE--later renamed Fundacao IBGE) were used.

Background

Many important changes have occurred in Brazil's agriculture in recent years. The most significant have been diversification of agricultural exports, rapid growth of wheat and soybean production, rapid modernization of the agricultural sector, 3/ and shortfalls in coffee production which led to a rapid depletion of once-plentiful coffee stocks.

1/ Economists, Foreign Demand and Competition Division, Economic Research Service.

2/ Unless noted otherwise, the term Sao Paulo will refer to the entire State of Sao Paulo, not just the city which is the capital of the same State.

3/ The term modernization, as used in this study, refers to the adoption of techniques and inputs, usually capital-intensive, which save on labor and bring about increased yields. The techniques and inputs most commonly referred to as modern include farm mechanization, fertilizer, pesticides, and improved seeds. The authors do not wish to imply a value judgment by the use of the term "modern."

Export diversification has been characterized by increased exports of various agricultural products, particularly sugar, beef, soybeans, soybean meal, corn, and concentrated orange juice, as well as mineral and manufactured products. The growth in these exports has led to a decline in the importance of coffee exports. As indicated below, coffee's share of total Brazilian export earnings declined from over 60 percent in the late 1960's to 20 percent in 1973:

Year	Percent	Year	Percent
1955-59	61	1969	42
1960-64	53	1970	36
1965	44	1971	28
1966	44	1972	25
1967	44	1973	20
1968	42		

Source: (81, 109, Feb., 1972).

The volume of coffee exports (table 1) remained about the same during 1960-73, while export volumes of most other agricultural products have increased. Of particular interest are corn--exported mainly to Italy, Spain, and Japan--and soybeans and soybean meal--exported principally to the European Community (EC). In the near future, it is expected that combined exports of soybeans and soybean meal will be more important, value-wise, than coffee exports.

The spectacular increase in wheat production that has occurred since the mid-1960's has permitted a cutback in imports of wheat (which still remains Brazil's major agricultural import). Growth in soybean production has accounted for the stepped-up exports of soybeans and products. The production of wheat and soybeans is indicated below:

Year	Wheat	Soybeans
	1,000 tons	
1959/60-63/64 1/	265	290
1964/65-68/69 1/	384	709
1969/70	1,146	1,332
1970/71	1,732	2,100
1971/72	2,030	3,340
1972/73	700	5,400
1973/74	1,928	7,000

1/ Annual average.

Source: (103) and reports from U.S. Agricultural Attaché, Brasilia.

Table 1--Principal agricultural exports, Brazil, 1960-72

Commodity	Average		1970	1971	1972	1973 1/	1970	1971	1972	1973 1/
	1960-64	1965-69								
	1,000 metric tons						U.S.$1 million			
Coffee 2/	1,015	1,037	1,020	1,034	1,084	1,111	982	872	1,057	1,344
Cotton	191	261	343	227	284	283	154	137	189	218
Cocoa beans	86	103	120	119	102	NA	78	62	59	88
Cocoa butter	16	19	19	21	27	NA	28	24	33	NA
Sugar	554	978	1,125	1,261	2,571	2,971	127	153	404	600
Beef	22	52	115	123	192	134	85	150	220	218
Soybeans	41	175	290	213	1,037	1,786	27	24	127	492
Soybean cake and meal	21	189	525	911	1,405	1,581	41	82	152	423
Corn	3/ 155	700	1,471	1,280	176	35	81	75	10	3
Castor oil	77	122	153	135	127	132	38	40	54	123
Peanuts	8	14	36	36	56	50	12	9	14	17
Peanut cake and meal	46	133	201	201	170	80	16	17	15	15
Peanut oil	2	2	32	63	77	NA	10	24	2	NA
Tobacco, unmanufactured	45	46	54	61	63	64	31	37	47	58
Orange juice concentrate	2	18	33	77	87	119	15	36	41	62
Hides and skins	11	32	45	26	29	NA	17	14	24	18
Rice	41	157	95	149	--	33	7	11	--	4
Wool	4	18	18	20	18	NA	12	15	26	NA
Sisal	128	144	136	139	145	NA	15	15	22	60
Brazil nuts	27	26	32	25	22	20	14	14	21	15

-- = less than 500 tons or $500,000.
NA = not available.

1/ Preliminary.
2/ Includes green coffee equivalent of soluble coffee exports.
3/ 700,000 tons in 1963; all other years small.

Sources: Reports from U.S. Agricultural Attache, Brasilia; (96, 93, 101, 119).

The following tabulation illustrates the changes that have occurred in Brazil's production and exports of coffee:

Year	Production	July 1 stocks 1/	Domestic consumption	Exports 2/
		1,000 tons		
1960-64	1,550	2,418	422	1,015
1965-69	1,394	3,293	496	1,037
1970	585	1,818	540	1,020
1971	1,416	1,118	540	1,034
1972	1,530	1,068	540	1,084
1973	858	3/ 864	540	1,111
1974	1,620	3/ 600	550	NA

NA = not available.

1/ Held by Brazilian Coffee Institute.
2/ Includes green equivalent of soluble coffee exports.
3/ Privately held stocks accounted for another 570,000 tons in 1973, and 96,000 in 1974.

Source: Reports from agricultural attache, Rio de Janeiro and Brasilia; (94, 103, 63, 81).

A series of events led to the shortfalls in coffee production. In 1962-64 and again in 1966-67, the Government subsidized the removal of coffee trees. Major frosts occurred in 1963, 1969, and 1972, and these were more damaging than frosts in earlier years because coffee production had shifted southward to higher risk areas. Compared with prices received for alternative crops, coffee prices were low (72, pp. 12-39). Finally, coffee production in recent years has suffered from coffee rust disease (Hemileia vasatrix). During the first year of the Federal Government's 1972-74 coffee renovation program, which subsidizes the planting of new coffee trees, loans for more new trees were applied for in Minas Gerais than in any other State. This may indicate a reversal of the migratory trend of the 1950's and 1960's, with coffee now moving back into frost-free zones.

The rapid modernization of Brazilian agriculture, particularly in the southern half of the country, can be measured in part by the rapid increase in the use of farm machinery and chemical fertilizers. Between 1960 and 1970, the number of tractors in use in Brazil increased by 147 percent, and fertilizer use increased 228 percent. Government policies during the period greatly increased the general availability of credit; provided credit at below market rates for the purchase of tractors, fertilizers, and other "modern" inputs; and removed taxes on tractor production. Labor legislation which increased the real wages and other benefits to farmworkers also provided farm owners with an incentive to adopt less labor-intensive techniques.

NATURAL RESOURCES

Sao Paulo's natural resources--soils, topography, rainfall--are among the best in Brazil for the development of agriculture. Among the larger States, Rio Grande do Sul and Parana are probably the only ones that approach Sao Paulo's natural

endowments. These two States, however, are located mostly in temperate zones and are thus unable to support as wide a range of crops as Sao Paulo, which lies mostly in the tropical zone. Because of these advantages, a larger proportion of Sao Paulo's total land area is tilled than in other Brazilian States. In 1970, 19 percent of Sao Paulo's total land area was in crops, compared with only 10 percent for Brazil, excluding the frontier areas of the Central-West and the Amazon. In 1960, crops and pastures accounted for 78 percent of Sao Paulo's area, compared with 35 percent for Brazil excluding the frontier area.

Sao Paulo covers an area of 248,000 square kilometers, or about the same area as New York and Pennsylvania combined. The State accounts for 2.9 percent of Brazil's total area. Its 1970 population of 18 million--19 percent of Brazil's total--was 80 percent urban, compared with a national urban percentage of only 56 percent. Forty-six percent of Sao Paulo's inhabitants live in the greater Sao Paulo City area.

Regions

Sao Paulo can be divided into four main geographic regions: the Atlantic Coast, the Atlantic Highlands, the Paleozoic Depression, and the Western Plateau (fig. 2). The coastal strip contains only 3 percent of the State's farmland and is agriculturally important only for bananas. The Atlantic Highlands are composed mostly of a mountain range which rises sharply above the coastal lowlands and slopes to the west. This region contains the Paraiba Valley, an important area for irrigated rice, potatoes, and dairying. The Paleozoic Depression, with flat to hilly terrain, consists mostly of poor soils, but has some spots of very good soil. Sugarcane and corn are the most important crops in this region. The Western Plateau, Sao Paulo's richest agricultural area, covers about three-fifths of the State and in 1970 contained 74 percent of the State's crop area. It consists of plains and gently rolling land sloping from altitudes of 800 to 1,200 meters (2,600 to 3,900 feet) in the East to 250 to 300 meters (800 to 1,000 feet) at the Parana River in the West. Most of the State's cotton, corn, rice, peanuts, coffee, beef, and over half of its sugar are produced in the Western Plateau region.

The natural vegetation over most of Sao Paulo consists of semidecidious forest. The exceptions were the Atlantic Coast region, which was covered with tropical rain forest and several patches of savanna mostly in the Paleozoic Depression. (16, pp. 19-22; 63, pp. 342-349; 40, p. 478).

Climate

Four-fifths of Sao Paulo lies north of the Tropic of Capricorn and has a tropical climate. Only in a small part of the southern interior can the climate be described as subtropical. There are a few areas--mostly in the southeast--where more than five frosts a year are likely, but the frosts occur in patches which are interspersed with many frost-free areas. On over half of the Western Plateau there is practically no chance of frost.

Rainfall ranges from 1,100 to 1,500 millimeters (43 to 59 inches) over most of Sao Paulo, although the coastal region receives over 2,000 millimeters (79 inches) a year. As in most of Brazil, Sao Paulo has distinct wet and dry periods, with the dry season in the winter, from April or May until September. South of the Tropic of Capricorn and along the coast there are no distinct wet and dry seasons (16, pp. 22-45; 84, part 1, pp. 14-15).

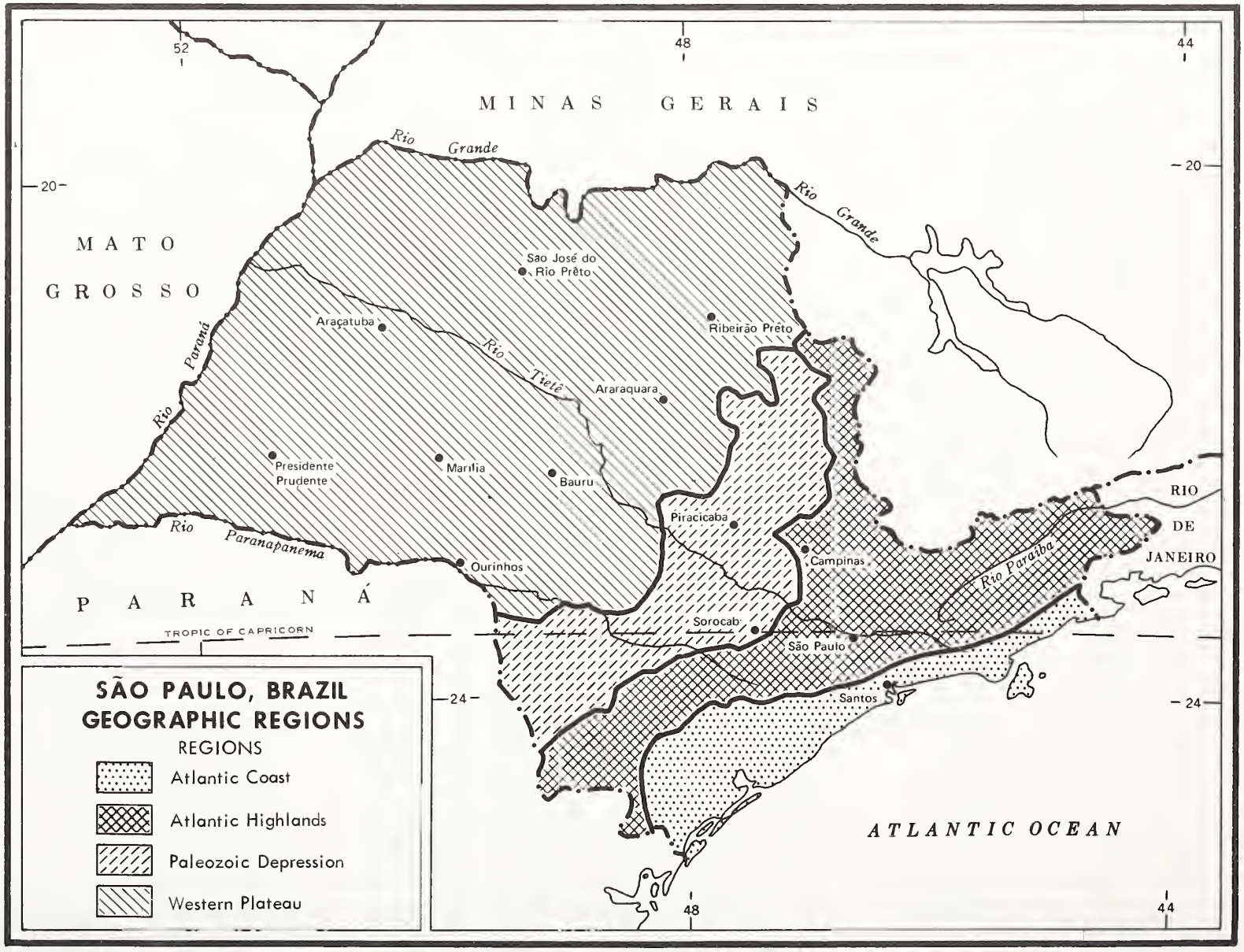

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Figure 2

Soils and Fertility

Sao Paulo's soils, especially those on the Western Plateau, are among the best in Brazil. However, some of these soils are quite susceptable to erosion and require careful management to maintain their fertility.

A relatively large proportion of Sao Paulo's soils are suited to agriculture. A comprehensive soil survey published in 1960 (16) classed the various soil groups as to their adaptability to agriculture as follows:

Quality	Percent of State land area
Good	35
Fair	6
Inadequate to fair	40
Inadequate	13
Not classified 1/	6

1/ Areas of associated soils in the Atlantic Coast and Atlantic Highlands regions where little agriculture is practiced.

Three soil groups--Terra Roxa Legitima, Terra Roxa Estructurada, and Podzolized soils on calcareous sandstone (Arenito de Bauru)--account for most of the good soil in Sao Paulo. The area covered by these three soils--about 35 percent of the State's land area--is mainly in the Western Plateau region (fig. 3). The authors of the soil survey observed that 60 to 80 percent of the farmland on the three soil groups was cropped, compared with 10 to 20 percent or 30 to 40 percent on almost all other soil groups. Although the 1960 Census of Agriculture indicates that these estimates are exaggerated, they do indicate the importance of the three soil groups to Sao Paulo's agriculture.

A fourth important soil group on the Western Plateau--known in Sao Paulo as Arenito de Botucatu--consists of the Dark Red Latosols-Sandy Phase. 4/ The soils of this group, found in the river valley areas, cover 20 percent of Sao Paulo's land area and account for most of the unshaded area of the Western Plateau on figure 3. A relatively small proportion of these poorer soils are cropped--the soil survey suggests 10 to 20 percent.

Outside of the Western Plateau, the most important soil groups are the Red-Yellow Podzolic soils, covering less than 7 percent of the State's area, and the Hydromorphic and Alluvial soils, which account for less than 3 percent of the State's area (16, 84; 51; 21, pp. 103-105, 131).

A study of soil nutrients in Sao Paulo, based upon soil analyses performed by the Instituto Agronomico de Campinas, was published in 1971. 5/ The study found that 37 percent of Sao Paulo's cultivated area was poor in nitrogen (less than 1.5 percent organic matter). Soils rich in nitrogen--23 percent of cultivated area--are located generally in the Atlantic Coast and Atlantic Highlands regions and in those areas with Terra Roxa Legitima soil. Ninety percent of the State's cultivated area

4/ The term Arenito de Botucatu usually includes Terra Roxa Estructurada soils in addition to the soils that are discussed here.

5/ Reported in (124, May through July, 1971).

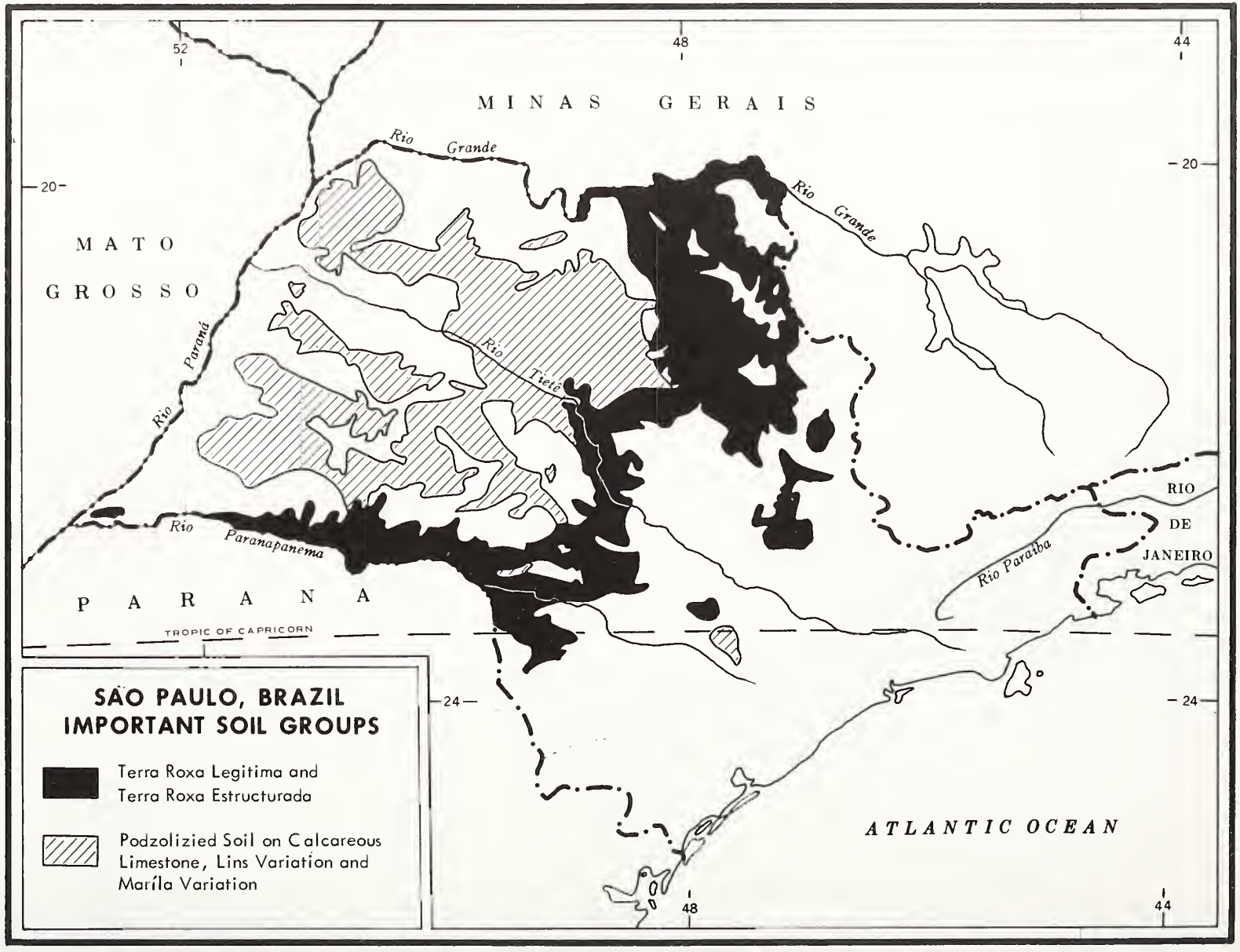

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Figure 3

is low in phosphorus (below .10 milligrams per 100 grams of soil). The situation for potassium is the opposite, with 99 percent of cultivated area having medium to high levels (.12 milligrams or more per 100 grams of soil). Fifty-eight percent of the cultivated area in Sao Paulo has a serious problem of excess acidity, with pH levels of 5.50 and below. Excess acidity problems are the worst in the eastern part of the State (124).

PRODUCTION TRENDS, 1950-73

Aggregate Analysis

Sao Paulo accounts for approximately 20 percent of Brazil's agricultural production. The State's agricultural output averaged about $1 billion annually in 1968-70. 6/ Following in importance were Parana with $618 million, Rio Grande do Sul with $602 million, and Minas Gerais with $574 million. Sao Paulo ranks first in the production of cotton, oranges, peanuts, sugar, tomatoes, beef, and eggs, and second in bananas, coffee, corn, milk, and pork (table 2).

Between 1952-56 and 1966-70, agricultural production grew at an average annual rate of 2.6 percent in Sao Paulo 7/ and 3.6 percent in all of Brazil. 8/ A greater expansion of cropland outside of Sao Paulo accounted for the different growth rates. Between 1948-50 and 1967-69, 92 percent of the increase in Brazilian crop production was due to an expansion in area, while for Sao Paulo, 97 percent of the growth in production was due to increased yields (table 3).

Figure 4 shows the production areas of eight commodities in Sao Paulo. Of the commodities, corn is the most diffused throughout the State, while peanuts are the most concentrated. There is a substantial overlap among the principal cotton, corn, rice, peanut, and cattle areas. Corn is the only crop with a major portion of its area in the relatively less productive southeastern part of the State. The coffee area coincides closely with the cotton, corn, rice, cattle, and peanut areas, but most of the sugar area lies to the east of the other crop-producing areas. Soybeans are concentrated in a fairly limited region.

Major Annual Crops

Corn

Corn covers more area--25 percent of the State's cropland in 1973--than any other crop in Sao Paulo. It is grown in all parts of the State by all types of producers, from small subsistence farmers to large commercial farmers using modern techniques. Production increased from 1.2 million tons in 1950-54 to 2.6 million tons in 1969-73, a 4.3-percent annual growth rate (table 4).

Area planted to corn almost doubled between 1950 and 1971 but then declined somewhat in 1972 and 1973. Growth in area planted was steadier than for other commodities with substantially less year-to-year fluctuation from the growth trend (fig. 5). Yields continued a slow increase after a drop in the mid-1950's, but they still remain relatively low. Better farmers consistently obtain yields of 2,500 to 3,000 kilos per hectare, which are about a ton per hectare above the State average, but the average is kept down by the inadequate use of fertilizer, and by

6/ Calculated from value of 28 leading commodities, IBGE data in (93).
7/ Calculated from (74, p. 31).
8/ Calculated from (103) and Econ. Res. Serv., U.S. Dept. Agr., unpublished data.

Table 2--Sao Paulo's share of Brazilian production and rank among States for production of selected commodities, 1965-69 and 1970

Commodity	1965-69	1970	1970
	Percent		Rank
Bananas	15	13	2
Beans	8	7	4
Cocoa	--	--	1/
Coffee	23	2/ 39	2/ 1
Corn	20	19	2
Cotton	51	36	1
Manioc	8	6	8
Oranges	42	45	1
Peanuts	84	76	1
Potatoes	27	23	3
Rice	15	14	4
Soybeans	5	6	3
Sugar	36	38	1
Tobacco	3/	3/	14
Tomatoes	47	49	1
Wheat 4/	1	1	4
Beef 5/	29	29	1
Eggs	30	32	1
Milk	20	19	2
Pork 5/	16	16	2

-- = not significant.

1/ Three States accounted for 99.6 percent of Brazilian production.
2/ Sao Paulo's large share of the coffee crop was due to an unusually small crop in Parana.
3/ Less than 0.5 percent.
4/ Crops harvested, 1964-68 and 1969.
5/ Sao Paulo's share is exaggerated because many of the animals slaughtered in Sao Paulo are raised in neighboring States.

Source: (93).

Table 3--Factors responsible for increased crop production in Sao Paulo and Brazil, 1948-50 to 1967-69

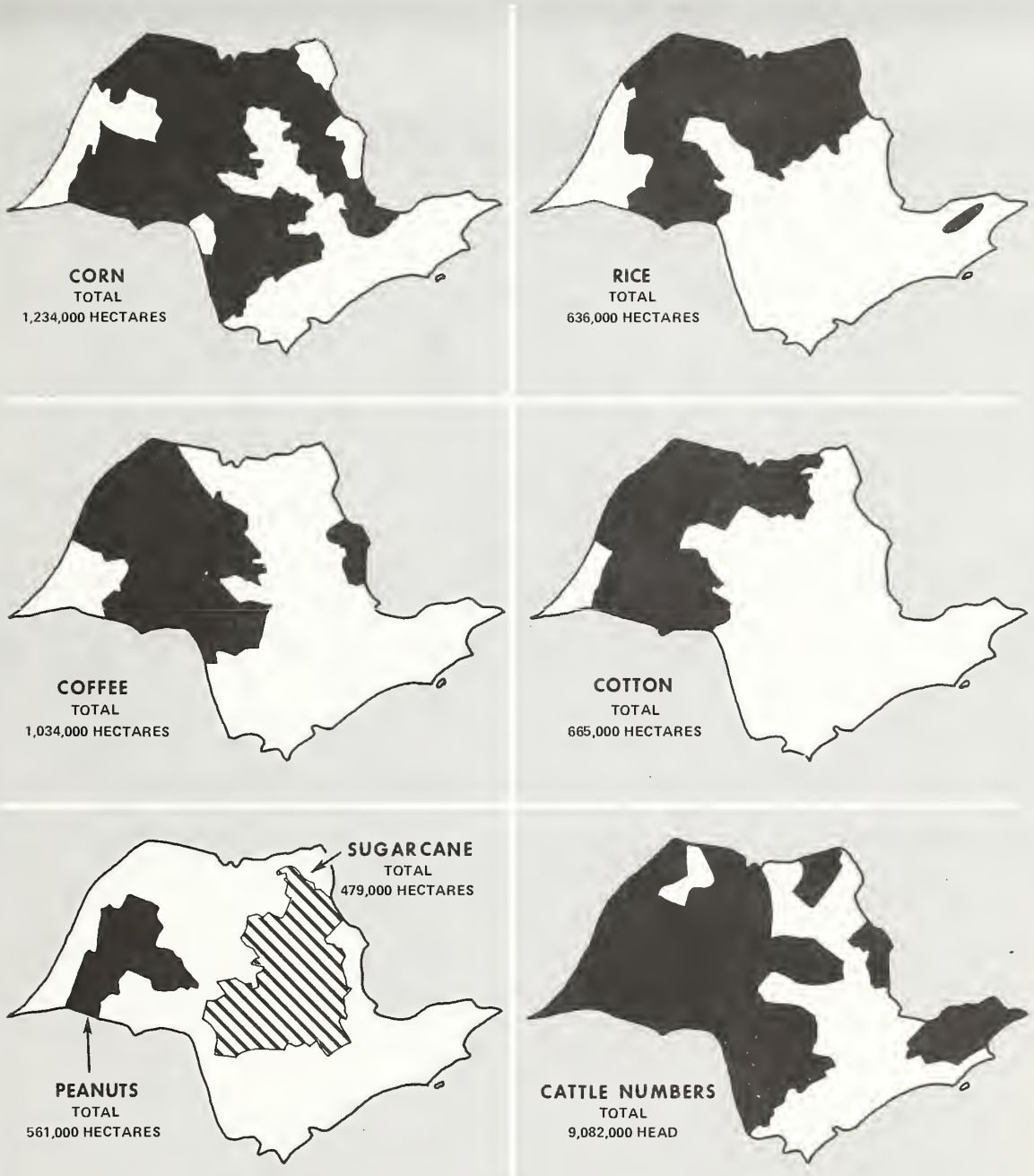
Factor	Percent of increased production due to cited factor in--	
	Brazil, 23 crops 1/	Sao Paulo, 16 crops 2/
	Percent	
Increased area	+92	+35
Increased yields	+20	+97
Changes in types of crops	-1	-32
Changes in location	-11	--

-- = not calculated.

1/ Based on IBGE data.
2/ Based on IEA data.

Source: George Patrick, Sources of Growth in Brazilian Agriculture; The Crop Sector, Brazil, Ministry of Planning, IPEA. Cited in (63).

SÃO PAULO, BRAZIL
CROP AREAS, 1966 AND CATTLE NUMBERS, 1970



CROP AREAS AND CATTLE NUMBERS ARE CONCENTRATED IN THE SHADED AREAS (75 PERCENT OF TOTAL AREA OF EACH CROP; 75 PERCENT OF TOTAL CATTLE NUMBERS) *(FOR EXAMPLE, THE AREA IN CORN IN SAO PAULO WAS 1,234,000 HECTARES; 926,000 HECTARES WAS GROWN IN THE SHADED AREA.)*

SOURCE: CROPS: IBGE, PRODUCÃO AGRICOLA; CATTLE: CENSUS OF AGRICULTURE, 1970

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Figure 4

Table 4--Changes in production, area, and yield of selected crops, Sao Paulo, 1950-73

Item	1950-54	1955-59	1960-64	1965-69	1970	1971	1972	1973	Average rate of change, 1950-54 to 1969-73
				1,000 tons					Percent per year
Production:									
Corn	1,151	1,232	1,964	2,374	2,820	2,760	3,000	2,598	4.3
Cotton 1/	216	158	195	192	250	220	218	197	0.2
Rice	660	570	737	737	780	348	660	582	-0.7
Peanuts 2/	156	245	447	566	620	638	645	325	6.9
Soybeans	2	5	6	33	98	94	222	330	3/
Coffee	486	680	440	448	258	4/ 648	540	450	-0.3
Sugarcane	9,781	17,093	23,711	33,823	42,500	38,300	44,200	42,000	7.5
Oranges	141	410	903	1,304	1,774	1,840	2,428	2,840	3/
				1,000 hectares					
Area:									
Corn	881	1,092	1,335	1,412	1,476	1,694	1,500	1,300	2.6
Cotton	1,086	557	572	441	702	605	630	430	-3.4
Rice	505	562	719	835	636	557	503	519	0.9
Peanuts	145	186	398	461	448	506	504	264	6.0
Soybeans	2	5	5	24	67	87	127	200	3/
Coffee	1,417	1,610	1,174	716	681	694	694	734	-3.7
Sugarcane	225	349	491	659	758	823	819	802	6.7
Oranges	18	49	100	123	189	213	251	305	14.2
				Kilograms per hectare					
Yields:									
Corn	1,306	1,128	1,471	1,681	1,910	1,629	2,000	1,998	1.7
Cotton 1/	199	284	341	435	356	364	346	458	3.7
Rice	1,307	1,014	1,025	883	1,225	625	1,312	1,121	-1.5
Peanuts 2/	1,074	1,317	1,123	1,228	1,385	1,261	1,280	1,156	0.8
Soybeans	1,011	1,104	1,138	1,382	1,462	1,080	1,748	1,650	2.2
Coffee	342	422	375	626	379	935	778	613	3.5
Sugarcane	43,471	48,977	48,291	51,324	56,106	46,537	52,747	52,369	0.8
Oranges	7,833	8,367	9,030	10,602	9,391	8,638	9,673	9,311	0.9

1/ Cotton lint yield estimated at 33 percent of seed cotton production.
2/ In shell.
3/ More than 15 percent.
4/ Does not agree with Brazilian Coffee Institute estimates.

Source: Calculated from (74), other IEA reports, and attaché dispatches.

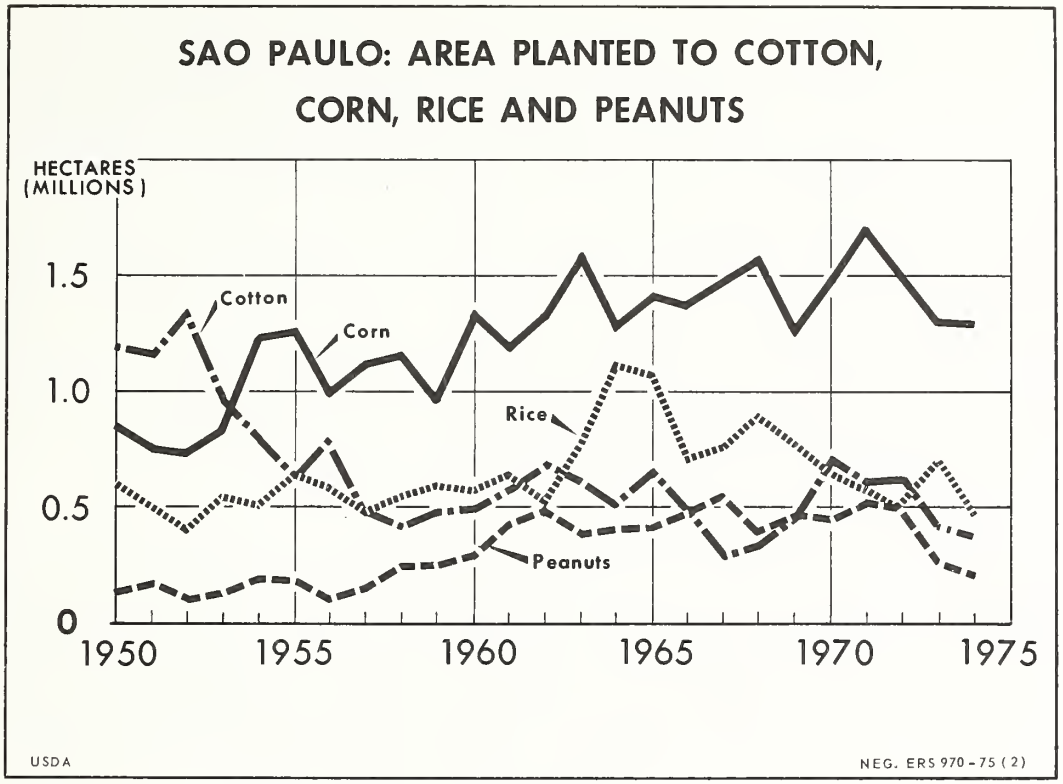

Figure 5

the large number of producers (mostly small scale) who do not use modern techniques (31, pp. 2, 7; 39, p. 7). Even the yields obtained by the best farmers are substantially below average yields in the United States.

Cotton

Sao Paulo has been an important cotton-producing State since the 1930's, and in 1973 accounted for 30 percent of total Brazilian production. Area planted to cotton declined substantially during the mid-1950's, but because of much improved yields, production in recent years has been equal to the 1950-54 level. The principal reason for the decline was the withdrawal of many marginal farmers who were disappointed with low yields caused by a period of unfavorable weather, increased insect attacks, and soil depletion (84, part 1, p. 97; 62, p. 186).

Cotton yields in Sao Paulo have risen at a faster rate--3.7 percent per year--than those of any other important crop. The withdrawal of marginal farmers from cotton production and the subsequent concentration of production in the hands of larger producers employing modern techniques was surely a factor in this achievement. Yields in 1973 were more than double 1950-54 yields.

Statistics on area planted, published by IBGE in 1957 and 1966 (18, 19), indicate that cotton production in Sao Paulo tended to shift toward the northern part of the Western Plateau. This shift may have been due to higher yields in this area. Estimates of production in 1970 show cotton lint yields of 376 kilograms per hectare in the northern part of the Western Plateau, compared with only 262 kilograms in the southern part (99).

Rice

Rice production in Sao Paulo increased relatively little over the past two decades. The increase in area planted was offset by declining yields which were due in part to the changing quality of the soil used for rice production. In the early 1950's, rice was often planted on virgin lands or between the rows of new coffee. Now rice is generally grown as a single crop on the less fertile soils. The low yields can also be attributed to the climatic risks inherent in dryland rice production. (About 97 percent of Sao Paulo's rice area is nonirrigated.) The high risk of crop failures under such growing conditions discourages heavy investments in farm inputs (52, p. 8; 44, p. 22; 9, p. 20; 118, May-June, 1973, p. 7).

Between 1957 and 1966, rice production tended to shift toward the northwestern corner of the Western Plateau (18, 19). An examination of 1970 yields indicates that there was no absolute yield advantage to growing rice in this area. However, rice did have a relative advantage over coffee and cotton in the area. 9/

Peanuts

Peanut production in Sao Paulo increased fourfold between the early 1950's and 1970, and in the process became one of the State's major crops. Production, however, remains confined to a relatively small area of southwestern Sao Paulo around Marilia and Presidente Prudente. Planted area declined sharply in 1973 and 1974, causing the State's share of total Brazilian output to fall from 75 percent in 1971 to 50 percent in 1973. The decline is attributed to lower producer returns for peanuts relative to other crops, particularly soybeans and castor beans. The producer price of castor beans, relative to peanuts, rose dramatically in 1972 and remained at high levels through early 1974.

Other Annual Crops

Soybeans

Soybean production in Sao Paulo has increased rapidly since 1966. Output varied between 3,000 and 8,000 tons per year during the 1950's and early 1960's, but by 1974 reached 642,000 tons. Most of the soybeans in Sao Paulo are grown on large mechanized farms, mainly in the area near Ribeirao Preto, but they are also spreading to other areas of the State, particularly the peanut area around Marilia.

In the principal soybean-producing States of Rio Grande do Sul and Parana (about 90 percent of the 1973 crop) soybeans are often double cropped with wheat. Much of the growth in Brazilian soybean production--over 900 percent between 1968 and 1974--can be attributed to this practice. In Sao Paulo, however, soybeans are usually grown as a single crop. The apparent success of the crop in Sao Paulo indicates a good future for Brazilian soybeans outside the wheat-growing regions (66, pp. 2-3; 112, June 1968; 45, p. 23).

Wheat

Wheat is a minor crop in Sao Paulo, but its production has increased somewhat in recent years. Output averaged a little over 4,000 tons during the 1960's but grew to 74,000 tons in 1974 10/--approximately 4 percent of total Brazilian output. Sao Paulo

9/ Coffee and cotton yields in 1970 were substantially below statewide averages in the Sao Jose do Rio Preto zone, but rice yields were only slightly below the statewide average.

10/ Crop harvested in late 1973 (spring of the 1973/74 crop year).

wheat production was concentrated in the natural grasslands of the Campos Gerais in the western portion of the Paleozoic Depression, but the recent expansion in wheat area has been mostly in the Western Plateau near the margin of the Parapanema River east of Orinhos. Sao Paulo wheat in the older Campos Gerais production area was not double cropped with soybeans, but this practice is used in the new wheat area on the Western Plateau (88, pp. 56-57; 7).

Other

Production of other minor annual crops in Sao Paulo is shown in the following tabulation:

Crop	1950-54	1969-73
	1,000 metric tons	
Beans	124	125
Manioc	716	1,711
Castor beans	42	70
Potatoes	273	405
Tomatoes	105	458

Source: (74).

Beans, which account for more than one-half the area in the above crops, are produced by labor-intensive, traditional methods. Castor beans are also produced with these methods. On the other hand, production of potatoes and tomatoes is more technically advanced. Manioc is produced under widely varying methods.

Perennial Crops

Coffee

Coffee yields increased during 1950-73, while area planted fell to a level less than one-half that of the mid-1950's. Despite the fall in production, coffee is still Sao Paulo's second most valuable crop. The producer shift out of coffee cultivation was prompted by low prices in the early 1960's, the desire to have the production flexibility possible with annual crops, and the coffee diversification schemes of the mid-1960's which provided incentives for replacing older stands of coffee with annual crops and pasture.

Sugar

Sugar is the most important crop, in terms of value, in Sao Paulo. The rapid increase in production since the early 1950's--7.5 percent per year--has been due mostly to increased area, mainly in the Paleozoic Depression and the eastern portion of the Western Plateau. Much of the expansion has been at the expense of former pastureland (22, pp. 22-23; 65).

Fruit

Sao Paulo's orange production, much of it for export as fresh fruit or as concentrated juice, has grown spectacularly. The citrus-growing area corresponds closely to the sugarcane area (67; 22, pp. 22-23).

Bananas, mostly for the domestic market, are grown in the Atlantic Coast region. Area cultivated declined through the 1960's, but production levels were maintained as yields more than doubled (74, p. 29).

Livestock

Sao Paulo is one of Brazil's leading cattle-producing States. According to Brazil's 1970 Census of Agriculture, only Minas Gerais, Rio Grande do Sul, and Mato Grosso had larger cattle herds than did Sao Paulo. The following tabulation shows the growth of Sao Paulo's cattle herd:

Year	1,000 head	Percent of Brazilian herd
1950	5,880	13
1960	7,155	13
1970	9,082	12

Source: (13, 24).

Most cattle in Sao Paulo are mixed Brahman (Zebu)- native breeds.

Cattle slaughter is greater in Sao Paulo than in any other State (93) because large numbers of live cattle, both fat and lean, are brought to Sao Paulo from Mato Grosso, Goias, and Minas Gerais. The lean cattle, 2 to 3 years old, are fattened for 8 to 12 months on pastures in the western and north-central sections of the Western Plateau (8, pp. 44-47). Average slaughter weight of cattle in Sao Paulo was 220 kilograms (485 pounds) in 1966-70, compared with an average of 217 kilograms in 1950-54 (93; 8, pp. 44-47; 114, Jan. 12, 1970; 74, p. 305).

Sao Paulo is Brazil's second largest producer of milk, following Minas Gerais, and is the country's leading producer of broilers and eggs. Hog numbers in the State declined by 19 percent between 1960 and 1970, and by the latter year accounted for only 6 percent of the country's total. However, large numbers of hogs raised in neighboring States are brought to Sao Paulo for slaughter.

FARMING PATTERNS

Farm Characteristics

Large farms employing several workers have a dominant place in Sao Paulo's agriculture, just as in the rest of Brazil. In 1970, farms of 50 hectares and over accounted for 20 percent of the farm units in Sao Paulo, 82 percent of the farmland, and 60 percent of the land in crops (table 5). The average farm size was 63 hectares,

Table 5--Classification of farms by size, Sao Paulo, 1970 1/

Size	Number of farms 2/	Farm area	Cropland	Farm-workers	Average farm size	Farmland per worker	Cropland per worker	Workers per farm
	Percent of total				Hectares			Number
Hectares:								
Less than 10	40.2	3.3	10.9	26.1	5	2	1.3	2.9
10 to 50	39.7	14.8	28.6	34.9	24	6	2.7	4.0
50 to 200	14.5	22.3	23.5	18.1	97	17	4.2	5.6
200 to 1,000	4.9	31.3	24.3	14.1	402	31	5.6	13.0
1,000 and over	.8	28.2	12.6	6.7	2,331	58	6.1	39.9
Total	100.0	100.0	100.0	100.0	63	14	3.2	4.5

1/ There were 327,371 farms covering 20.6 million hectares, with 4,772,758 hectares in crops and 1,475,325 farmworkers.

2/ Number of individually owned pieces of farmland. Actual number of farm management units is less since many farm operators own more than one noncontiguous plot.

Source: (24).

and the average size of farms in the 50- to 1,000-hectare category was 174 hectares. 11/ The largest farms, averaging 69 hectares, were found in the Western Plateau region and the smallest, averaging 47 hectares, were found in the generally mountainous Atlantic Highlands region.

Between 1960 and 1970, there was a slight increase in average farm size in Sao Paulo, while in the rest of Brazil, average farm size declined from 75 to 59 hectares. Para and Espirito Santo were the only other States to show an increase in average farm size. There was little change in the percentage of farmland contained in units of 50 hectares and more in either Sao Paulo or the rest of the country. In 1970, 39 percent of the farm labor force worked on farms of 50 hectares or larger, compared with almost 48 percent in 1960.

Many large landowners in Sao Paulo are switching to modern methods of production (such as heavier use of purchased inputs like machinery and fertilizer and efficient land management techniques 12/), but a 1967 cadastral survey 13/ judged that only 8 percent of the State's farms (24,000 units) operating on 20 percent of its farmland were "rural enterprises." 14/ However, Sao Paulo, with 28 percent of Brazil's rural enterprises, was way ahead of the rest of the country in this respect. Outside of Sao Paulo, only 2 percent of the farms operating on less than 4 percent of the farmland were classed as rural enterprises. Except for a few very large farms, all other farms were considered to be either inefficiently operated or too small to earn an adequate living for a farm family.

Crop-Land Relationships

Crop rotation pactices, as known in the United States, are not widely used in Sao Paulo or elsewhere in Brazil. Most rotation occurs because of shortrun economic considerations, like higher expected returns for one crop than for another. Most commonly, in the case of annual field crops such as rice, corn, cotton, and peanuts, the same crop is grown on a field for 1 to 5 years, and then seeded to pasture for approximately the same amount of time. However, a certain amount of crop rotation is used with cotton to retard the development of diseases (17, 52, 69).

Double cropping is of limited importance in Sao Paulo. Of the double-cropped commodities, peanuts are the most important. The first crop (wet season) is harvested from December to February, and the second crop (dry season) is planted directly afterwards and harvested between May and July. During 1965-69, the first crop averaged 269,000 hectares, and the second averaged 193,000. In the Paraiba Valley, potatoes

11/ Brazil's agricultural census data tends to underestimate actual average farm size because each unit of land is counted as a separate farm, regardless of its ownership. Thus, if a person owns more than one plot of land (a relatively common phenomenon), each plot is counted as a separate farm, even if they are managed as a unit.

12/ See pages 34-37 and 45-48.

13/ This cadastral survey, conducted by the Brazilian Agrarian Reform Institute (IBRA) is considered to be unreliable, but it is used here because it closely parallels the IEA farm number and area data collected the same year. The results of the cadastral survey are reported in Anuario Estatistico do Brazil, 1968.

14/ A "rural enterprise" is defined as a farm able to fully employ from 4 to 2,400 people; that is exploited rationally and economically according to criteria set for its region; whose utilized farm area is 50 percent or more of that potentially usable; and which meets minimum standards set by IBRA for yields, social conditions, and farm income.

and rice are sometimes double cropped, with rice using the residual fertilizer from the potato crop. Also, there are two annual bean crops, the first grown in association with other crops, and the second usually grown as a single crop (10, p. 3). Outside of Sao Paulo, the only important instance of double cropping is that of wheat and soybeans in Rio Grande do Sul and Parana.

Associated cropping (more than one crop in a field) is not as important in Sao Paulo as in many other Brazilian States. The practice is most significant in the cases of corn and beans. Surveys in 1965 found that 20 percent of the State's corn area and 41 percent of its bean area were intercropped (87, p. 36). Corn, beans, rice, and other crops are also planted between rows of coffee trees, especially young trees which have not yet started to produce. These crops are used for the subsistence of workers on the coffee farm or for the farm owner's livestock. In 1960, no more than 25 percent of the State's coffee area was intercropped (84). Associated cropping is apparently declining in importance for most commodities and is most important in subsistence plots for crops not destined for the market.

Agricultural Expansion

Agricultural settlement of Sao Paulo was closely related to the expansion of coffee cultivation which occurred from the mid-1800's to the 1950's (with a lapse in the 1930's and 1940's) and, to a lesser extent, the growth of cotton production in the 1930's and 1940's. Crop production reached the Western Plateau region before the end of the nineteenth century and gradually expanded, pushing the frontier westward until it eventually spilled beyond the State. As coffee production moved westward, much of the land in the older areas was taken out of coffee and put into pasture or other crops. Cash crop production began to diversify in the 1930's with the emergence of cotton as a major crop. Rice, corn, sugar, peanut, and citrus production also began to grow in importance. By 1960, the Sao Paulo agricultural frontier had disappeared, and any additional increase in cropland had to come from more intensive use of established farmland.

The westward movement of coffee production in Sao Paulo led to the theory of the "hollow frontier." In 1942, the geographer Preston James advanced this theory:

> "As the new frontier rolls westward through the wreckage of the forest it leaves behind it a land rapidly depopulated and abandoned" (40, p. 500).

A well-known Brazilian agricultural economist described the hollow frontier theory in more detail in 1960:

> "It is known that one of the most typical characteristics of agriculture in Sao Paulo and neighboring States is a movement toward the interior in search of new land. When farmers find their land depleted due to erosion--the result of planting the same crop year after year--they are prompted to transfer it to pasture or to simply abandon it and move on to new areas where the fertility of virgin soils will permit bountiful crops without applying improved technology. They take with them the workers needed to clear and cultivate the land. Several years later when their new land has in turn been depleted they repeat the same process: The poorest areas are put into pasture; cropland is reduced; excess labor is dismissed; and they end up by again heading for new areas in search of crops on virgin soil" (61, p. 4).

Despite the rather wide acceptance of the hollow frontier theory, it does not appear to apply to the recent agricultural development of Sao Paulo. If there were a hollow frontier in Sao Paulo, one would expect to find a higher proportion of cropland on farms in the western portion of the Western Plateau than in its eastern portion. However, analyses of the 1960 and 1970 Censuses of Agriculture show this is not the case. In 1960, the western half of the Western Plateau region had 26 percent of its farmland in crops, compared with 28 percent in the eastern half. In 1970, farmland in crops had increased to 29 percent in the eastern half and declined to 22 percent in the western half. 15/. The higher proportions of cropland in the eastern portion of the plateau were likely due to the better distribution of good soils in that area (fig. 3) and the use of fertilizer to renovate "wornout" soils.

Changes in Farmland Utilization

1950-73 Trend

Although total farmland in Sao Paulo increased since 1950, it is of greater significance that an increasing proportion of farmland is being utilized for crops and pasture (table 6). Crop and pastureland, accounting for 68 percent of total farmland in 1950, took an 80-percent share in 1970. The greatest change was in pasture, which increased by more than 3 million hectares, or 36 percent, between 1950 and 1970. The proportion of improved (or artificial) pastureland increased from 43 percent in 1950 to 65 percent in 1970.

Since 1950, Sao Paulo's cropland has not increased as rapidly as the rest of Brazil's. According to the Census of Agriculture, Brazil's cropland increased by 78 percent between 1950 and 1970, compared with a 12-percent increase for Sao Paulo alone. These same data indicate that Sao Paulo's share of Brazil's cropland declined from 22 percent in 1950 to 14 percent in 1970. The slower rate of cropland expansion in Sao Paulo was due principally to the fact that Sao Paulo's agriculture was already well developed in 1950. Practically all of the good agricultural lands in the State were occupied by 1950, while in many other States, the 1950-70 period was one of expansion into previously unoccupied agricultural areas.

Total cropland in Sao Paulo rose from 4.3 million hectares in 1950 to 4.8 million hectares in 1960 and 1970 (table 6). The distribution of the cropland during 1950-73 is analyzed in table 7, which shows that total cropland (unadjusted) grew by 687,000 hectares, or 15 percent, between 1950-54 and 1969-73. Most of the growth was due to expanded area in annual crops.

Although land planted to sugarcane and oranges rose steadily during 1950-73, total perennial cropland showed little change due to the precipitous drop in coffee area beginning in 1959 and not reversed until 1971 (fig. 6). The decline in coffee during the early 1960's was directly offset by the rapid rise in area planted to the major annual crops--corn, cotton, rice, and peanuts. By 1970, these four crops accounted for 59 percent of total crop area and 85 percent of the area in annual crops, but in 1973 their combined area declined sharply. Beans and soybeans accounted for about two-thirds of the area in other annual crops. Soybean area increased from 7,000 hectares in 1965 to 335,000 in 1974. Cotton's share of cropland tended to decline over the period, with most of the drop occurring during the first 10 years. Corn and peanuts increased their share of cropland, while rice's share, apart from a spurt in the late 1960's, remained steady.

15/ Although similar, the boundaries chosen for the two subregions are different in each year. This is because of changes in census regions.

Table 6--Land use in Sao Paulo, 1950, 1960, and 1970

Use	1950	1960	1970	Change 1950-60	Change 1960-70
	1,000 hectares			Percent	
Cropland	4,258	4,768	4,773	12.0	0.1
Pasture	8,648	9,872	11,771	14.2	19.2
Other 1/	6,102	4,664	4,050	-23.6	-13.2
Total farmland	19,008	19,304	20,594	1.6	6.7

1/ Includes forest, uncultivated land, and unproductive land.

Source: (12, 14, 24), except pasture, 1970 (74). Other for 1970 is a residual.

Table 7--Distribution of cropland by crop, Sao Paulo, 1950-73 1/

Land use	Average 1950-54	Average 1955-59	Average 1960-64	Average 1965-69	1970	1971	1972	1973
	1,000 hectares							
Cropland								
Annual	2,998	2,863	3,665	3,729	3,860	3,952	3,785	3,261
Perennial	1,714	2,105	1,824	1,545	1,663	1,769	1,794	1,885
Total	4,712	4,968	5,489	5,274	5,523	5,721	5,579	5,146
Total, adjusted 2/	(4,537)	(4,730)	(5,125)	(4,852)	(5,190)	(5,361)	(5,230)	(4,901)
Proportion of total cropland in:								
All annuals	64	58	67	71	70	69	68	63
Corn	19	22	24	28	27	30	27	25
Cotton	23	11	10	8	13	11	11	8
Rice	11	11	13	16	12	10	9	10
Peanuts	3	4	7	9	8	9	9	5
Other annuals 3/	8	10	13	10	11	10	12	15
All perennials	36	42	33	29	30	31	32	37
Coffee	30	32	21	14	12	12	12	14
Sugar	5	7	9	12	14	14	15	16
Other perennials 4/	2	3	3	3	4	4	5	7

1/ Year ending June 30. Cropland estimates encompass area in 17 crops. Other commodities account for a negligible proportion of total cropland. These data are not consistent with census data shown in table 6. Distribution of cropland by crop is not available from 1960 and 1970 Censuses of Agriculture.
2/ Annual estimate data of land in annual crops and total cropland are overstated because land which is double cropped is counted twice--once for each harvest. Peanuts, beans, and potatoes are the most important commodities which are harvested twice during the year. The "adjusted total" subtracts the cropland used for the second crop of these 3 commodities from the cropland total.
3/ Beans, manioc, soybeans, castor beans, potatoes, tomatoes, wheat, and onions.
4/ Oranges, bananas, and grapes.

Source: Calculated from app. table 1.

Figure 6 shows that cotton, corn, rice, and peanuts have a dominant position among Sao Paulo's crops and that the total area planted to these crops fluctuated greatly from year to year during 1950-73. Area planted to the four crops ranged from 48 to 61 percent of total cropland.

The increase in area planted to corn, peanuts, and sugarcane in Sao Paulo came primarily from land previously in coffee and cotton and secondarily from land not in crops. This conclusion is based on a comparison of cropland utilization in 1957 and 1966 in the most important crop-producing regions of Sao Paulo. These 10 regions (out of a total of 35)--all in the Western Plateau area--had the most land in crops in 1966 and accounted for 63 percent of the State's cropland.

Within these 10 regions, the area planted to peanuts grew more than for any other crop (table 8). Peanuts apparently displaced land previously in cotton, which declined only in areas with increased peanut area, while increasing in some areas where total cropland expanded. Area planted to corn increased sharply, especially in regions where total cropland expanded. Rice area also increased somewhat in these regions. Land in coffee declined significantly in 9 of the 10 regions shown. The largest declines were in regions where total cropland also declined, implying that much of the former coffeeland reverted to pasture or other noncrop uses.

Most of the important sugar-producing regions do not coincide with the other important crop areas of western Sao Paulo (fig. 4, p. 12). Changes in the use of cropland in the four largest sugarcane-producing regions (42 percent of Sao Paulo sugarcane area in 1966) indicate that sugarcane area increased on land previously in coffee or not in crops.

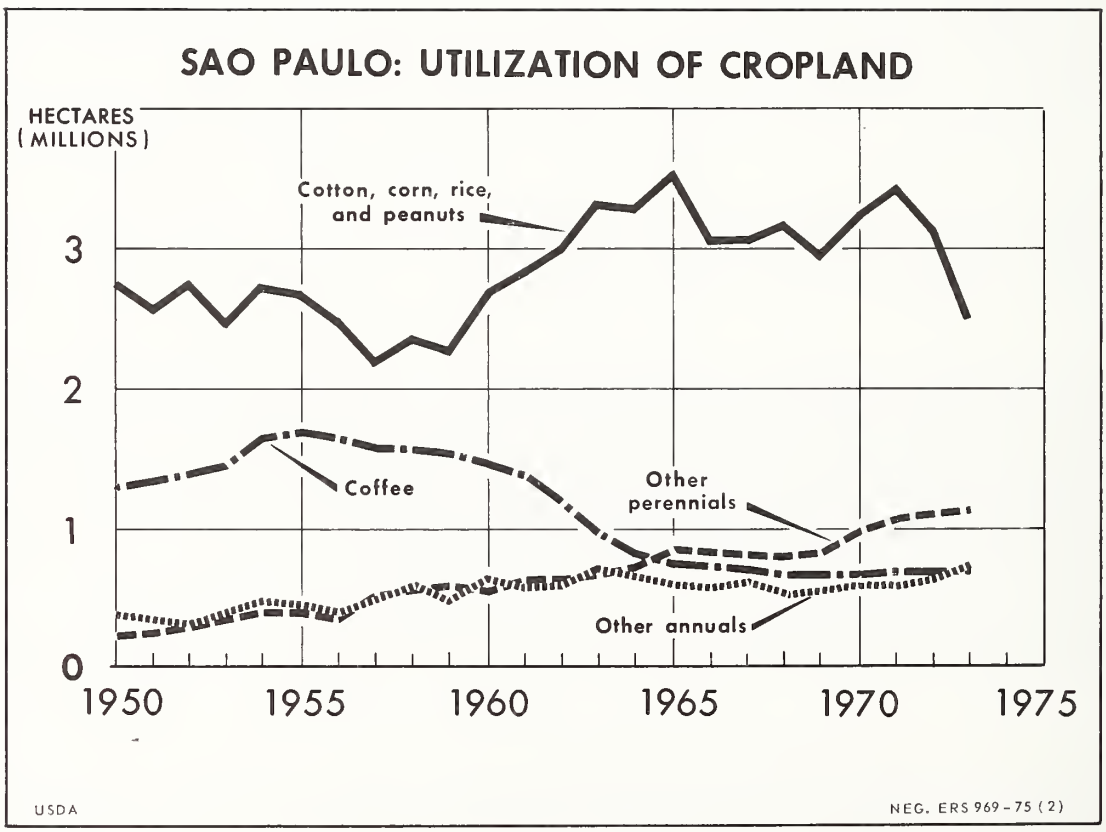

Table 8--Cropland and cattle numbers in selected regions of Sao Paulo, 1957-66, 1950, 1960, and 1970

Regions	Total area, 1966 1/	Change, 1957-66							Cattle numbers		
		Total 1/	Cotton	Corn	Rice	Peanuts	Coffee	Sugar	1950	1960	1970
	1,000 hectares								Percent of State herd		
Sao Paulo 2/	5,055	343	-81	250	49	417	-559	195	100	100	100
10 largest crop regions:											
Marilia	596	43	-81	10	-22	166	-22	2	4.1	6.3	6.3
Barretos	445	107	34	77	13	4	-40	4	9.0	6.7	6.5
Rio Preto	385	59	21	36	46	7	-46	-	9.1	8.1	8.3
Pereira Barreto	308	179	55	26	22	9	50	1	1.8	6.2	7.4
Assis	294	6	-5	1	2	12	-15	5	6.2	6.5	6.0
Presidente Prudente	270	-21	-131	11	-3	119	-15	-	3.7	5.5	6.1
Ribeirao Preto	231	-1	12	17	-5	2	-45	17	4.4	3.8	3.4
Catantava	226	-72	11	-13	5	16	-86	10	6.7	4.5	4.1
Aracatuba	224	-51	-10	-	-3	39	-74	-	8.2	8.4	7.2
Bauru	198	-77	1	1	-3	10	-92	7	6.2	5.0	4.9
Subtotal	3,177	172	-93	192	52	384	-385	46	59.3	61.0	56.9
Largest sugar regions 3/:											
Piracicaba	161	51	1	17	4	-	2	24	3.1	2.4	2.5
Rio Claro	105	19	-	-2	-	-	-5	21	1.5	1.2	.9
Araraquara	169	15	-4	4	7	9	-32	19	3.2	2.1	1.5
Ribeirao Preto	231	-1	12	17	-5	2	-45	17	4.4	3.8	3.4
Subtotal	666	84	9	36	6	11	-80	81	12.2	9.5	8.4

1/ 11 crops.
2/ Includes a total of 33 regions.
3/ Each region's area in sugar in 1966 was, respectively, in 1,000 hectares, 82, 53, 51, and 46.

Source: Calculated from (18, 19, 13, 24).

Because data on pastureland by regions are not available for recent years, each region's requirement for pastureland is estimated by its share of the State's total cattle herd in 1950, 1960, and 1970. If it is assumed that pasture productivity increased at the same rate in each region, an increase in a region's share of the herd would indicate an increase in pastureland. These criteria lead to the conclusion that area in pasture increased in the regions where cropland increased and decreased in the regions where cropland decreased. This conclusion points to little competition between crops and cattle grazing for the use of land, which concurs with known farming practices in Sao Paulo's Western Plateau, where the lowlands are generally used for pasture and the divides for crops (87, p. 14).

In the principal sugarcane-producing regions, pasture area apparently decreased as sugarcane area increased--implying a competitive relationship between sugarcane and cattle raising.

Factors Responsible for Changes

The changes in farmland utilization in Sao Paulo during 1950-72 were apparently due to the Government coffee eradication policies of the mid-1960's, changes in consumer demand, changes in Sao Paulo's comparative advantage over other States, and a gradual shift to less labor-intensive crops.

Coffee eradication--The sharpest decline in Sao Paulo's coffee area occurred during 1962-64 when the first coffee eradication program--a package of incentives for uprooting relatively unproductive coffee trees and replacing them with other farm enterprises--was in effect. Area planted to coffee declined from 1.4 million hectares in 1961 to 760,000 hectares in 1965.

Demand changes--Longrun changes in demand for agricultural products, as reflected in the relative prices received by farmers for agricultural commodities, apparently had some effect on farmland utilization in Sao Paulo.

Longrun trends (1950-70) in commodity prices and area planted (app. tables 2 and 3) were visually observed in order to identify the relationship between changes in area and changes in the relative prices of the various commodities. By the late 1960's and early 1970's, the price of peanuts was higher in relation to other commodities than in the early 1950's, and the price of cotton was lower. Over this period, the area planted to peanuts rose, while cotton area declined, an apparent reflection of cotton farmers' response to price. The relatively lower prices for cotton may also have affected the increased area planted to corn. Large shortrun shifts in the price of rice, such as the high prices in 1962 and 1963 and the low price in 1965, brought appropriate responses from producers. The large real decline in coffee prices during the late 1950's and early 1960's (prices were at low levels in 1959-61 and again in 1965-68) appears to be strongly related to the rapid decline in acreage during 1962-64.

Statistical analysis tends to support the above observations and provides a few additional insights into the relationship between price and area planted. Two recent studies examined supply response relationships for major crops, other than coffee, in Sao Paulo. Toyama and Pescarin (79) ran regressions on area and production using linear, semilog, and log-log equations for 1948-69. Although our main concern here is price response, these other independent variables were used in their regression equations: time trend, lagged production, lagged price of alternative commodities, wages, lagged wages, and an index of fertilizer prices. All price and wage data were deflated. The best equations for area planted to the most important crops are summarized in table 9. The best fitting equations were obtained for sugarcane, peanuts, and cotton. Most equations include several variables with statistically insignificant coefficients.

Table 9--Results of multiple regression analysis of agricultural supply response in Sao Paulo

Dependent variable (Area)	Source 1/	Type of equation	Multiple R^2	Independent variables 2/
Cotton	A	linear	.885	price t-2, trend, wages t-2, peanut price t-2, fertilizer price, area t-1 (.01) (.01)
	B	linear	.887	price t-1, cost of inputs t-1, castor bean price t-1, area t-1 (.02) (.20)
Corn	A	log-log	.751	price t-1, trend, rice price t-1, area t-1 (.01)
	B			No significant equations obtained
Rice	A	log-log	.773	price t-1, wages t-1, trend, corn price t-1, area t-1 (.01) (.20) (.20) (.20)
	B	linear	.719	price t-1, corn price t-1, area t-1 (.01) (.10) (.01)
Peanuts	A	semilog	.897	trend, wages, cotton price t-1, area t-1 (.20) (.01)
	B	linear	.913	price t-1, area t-1, trend (.01) (.01) (.02)
Beans	A	log-log	.617	price t-1, trend, area t-1 (.05) (.20)
	B	linear	.770	price t-1, area t-1, trend (.01) (.05)
Sugarcane	A	linear	.972	price t-1, trend, wages t-2, fertilizer price, area t-1 (.10) (.20) (.20) (.10)
	B	linear	.994	price t-1, cost of inputs t-1, trend (.05) (.01) (.01)

1/ A = Toyama and Pescarin (79), based on 1948-69 IEA data. B = Pastore (64), based on 1949-66 IEA data.
2/ The numbers in parentheses are significance levels as determined by t tests. Those variables without numbers below them were significant at less than .20.

Source: (64), (79).

Table 9 also shows the results of the best equations for a similar analysis by Pastore (64). He used area planted as the dependent variable in linear and semilog equations, with lagged price, lagged area, lagged price of alternative commodities, lagged cost of major purchased inputs (a composite index encompassing about 24 percent of the value of inputs used), and time trend. In the study, which covers 1949-66, the best fitting equations, as in the Toyama-Pescarin study, were obtained for sugarcane, peanuts, and cotton.

For this study, several simple and multiple linear regressions were run. Several variables were run against planted area, but the best results were obtained with the price and cross-price equations. Prices were expressed in constant 1969 cruzeiros. All the production, area, and price data used by Toyama and Pescarin, Pastore, and in this study are from Sao Paulo's Instituto de Economia Agricola (IEA). Toyama and Pescarin deflated prices by the IEA's index "C"--prices paid by Sao Paulo farmers for agricultural inputs. Pastore deflated all prices by a general index of prices paid to farmers, and prices for this study's analysis were deflated by the general price index No. 2 (60 percent wholesale price index, 30 percent cost of living index for Guanabara State, and 10 percent cost of construction index for Guanabara State) published by the Getulio Vargas Foundation.

The results of statistically significant price response equations (with expected signs) from all three sources are summarized in table 10. Note that, except for cotton, supply response to price in Sao Paulo is inelastic, that is, the expected change in planted area is proportionately less than the related change in price. Also, the low partial R^2's indicate that price changes only marginally explain the reasons for changes in planted area.

Most regressions of cotton's response to price showed insignificant results or resulted in a wrong sign. However, the equations shown in table 10 indicate that cotton has a greater response to its own price than other important commodities. Pastore found that cotton area was inversely related to castor bean prices, but the results were not highly significant. None of the studies found a significant relationship between corn area and its own price, but one regression found corn area to be responsive to the previous year's price of cotton. Rice was found to be responsive to price in several equations with relatively high levels of reliability. A relationship to the price of corn was also discovered.

Both the Toyama-Pescarin and Pastore studies found a significant relationship between peanut area and price. The work done for this study also found relationships between the area planted to peanuts and shortrun lagged prices of beef, corn, and rice. The relationship to beef prices was positive, indicating a complementarity between cattle raising and peanut production. The combined 1-year lagged prices of corn, rice, and beef were estimated to determine 71 percent of the variability in area planted to peanuts.

Although beans are not usually grown by large commercial farmers in Sao Paulo, they are apparently somewhat responsive to price incentives. Area in beans was also found to be positively related to the price of corn. This could be because of the practice of planting corn and beans together on small farms. 16/ The price elasticity of supply for sugarcane was apparently quite low.

Competition from other States--No measure of the comparative advantages of farmers in the various States was available for this study, but table 11 summarizes the absolute advantages in terms of value per hectare of growing various crops in

16/ In 1965, 41 percent of area planted to beans in Sao Paulo was planted in association with other crops (87, p. 56).

Table 10--Calculated elasticities and cross elasticities of supply for selected agricultural commodities in Sao Paulo

Dependent variable	Source 1/	Independent variable 2/	Time period	Type of equation	Level of significance 3/	Partial R^2	Calculated elasticity
(Area)							
Cotton	B	price	1949-66	linear	.01	NA	1.22
	C	price	1960-72	linear	.10	.24	.78
	B	price of castor beans	1949-60	linear	.20	NA	-.31
Corn	C	price of cotton	1960-71	linear	.10	.25	-.35
Rice	A	price	1948-69	log-log	.01	NA	.40
	B	price	1949-60	linear	.01	NA	.61
	C	price	1960-72	linear	.05	.35	.57
	A	price of corn	1948-69	log-log	.20	NA	-.32
	B	price of corn	1949-66	linear	.10	NA	-.52
Peanuts	A	price	1948-69	semilog	.05	NA	.65
	B	price	1949-66	linear	.05	NA	.47
	A	price of cotton	1948-69	semilog	.20	NA	-.65
	C	price of beef	1960-71	linear	.05	.33	.63
	C	price of corn	1960-71	linear	.20	.21	-.33
	C	price of rice	1960-71	linear	.20	.21	-.25
Beans	A	price	1948-69	log-log	.05	NA	.63
	B	price	1949-66	linear	.01	NA	.37
	C	price	1960-71	linear	.05	.36	.36
	C	price of corn	1960-71	linear	.01	.52	.67
Sugarcane	A	price	1948-69	linear	.10	NA	.27
	B	price	1949-66	linear	.05	NA	.12

NA = not available.

1/ A = Toyama and Pescarin (79). B = Pastore (64). C = Simple correlation analysis performed for this study.
2/ In all cases, variables are lagged 1 year.
3/ As determined by t test.

Table 11--Index of value per hectare of selected commodities in selected states of Brazil, relative to Sao Paulo 1950-71

Year	Cotton			Corn			Rice			Peanuts	Coffee	Sugarcane		
	Parana	Minas Gerais	Goias	Parana	Minas Gerais	Goias	Parana	Minas Gerais	Goias	Parana	Parana	Minas Gerais	Pernambuco 1/	Alagoas 1/
	Value per hectare in Sao Paulo = 100													
1950	92	100	67	72	99	101	92	88	80	74	201	58	69	85
1951	91	92	58	71	99	104	93	88	78	65	166	65	79	83
1952	135	97	86	69	99	98	69	75	64	61	210	62	74	79
1953	88	97	78	89	109	116	91	91	92	64	184	64	76	74
1954	102	86	59	79	118	156	92	69	88	73	92	53	63	69
1955	96	58	53	70	97	98	77	83	89	71	227	56	74	87
1956	82	58	70	68	86	74	66	88	87	74	55	45	74	85
1957	100	70	79	62	93	108	60	76	74	73	84	44	71	83
1958	92	59	40	71	54	123	72	78	71	57	148	48	80	88
1959	114	47	43	79	84	117	89	81	87	61	179	47	78	86
1960	93	45	50	87	94	115	89	92	88	48	214	39	67	71
1961	114	48	32	79	84	97	86	89	86	54	149	42	74	68
1962	124	53	50	79	83	89	75	76	74	61	247	40	63	66
1963	92	37	45	91	98	142	80	66	73	57	96	33	82	81
1964	96	32	50	81	103	135	98	93	100	77	191	33	73	83
1965	101	41	54	73	85	95	90	101	103	80	86	26	71	73
1966	103	45	58	79	86	97	81	82	104	93	83	41	81	90
1967	99	41	72	76	85	98	66	69	84	99	108	45	86	95
1968	129	35	72	84	82	117	75	93	106	114	122	42	91	98
1969	116	43	117	84	73	87	98	93	67	149	117	57	100	88
1970	89	43	108	76	73	74	86	83	63	89	26	50	94	99
1971	95	38	123	86	70	54	95	66	70	108	107	49	98	93

1/ The 2 most important sugarcane-producing States in the northeast of Brazil.

Source: Calculated from (93, 95).

Sao Paulo and some neighboring States. If competition from farmers in other parts of Brazil were an important factor for changes in Sao Paulo farmland utilization, one would expect returns per hectare to be higher in other areas for those crops which have decreased in importance in Sao Paulo (cotton, rice, and coffee). On the other hand, one would expect returns per hectare to be lower in other areas for those crops which have increased in importance in Sao Paulo (corn, peanuts, and sugarcane). This hypothesis appears to be substantiated in the cases of coffee and sugarcane and partly substantiated in the cases of cotton, corn, and peanuts.

In the case of cotton, the returns in Parana are only slightly higher than those in Sao Paulo. The returns for cotton in Goias began to increase relative to those in Sao Paulo at a rapid rate after the mid-1960's, which corresponds to the period of Goias' emergence as a major cotton-producing State, but follows by several years the major period of decline in Sao Paulo cotton area. The higher relative returns for peanuts in Parana in the late 1960's also correspond with an expansion of peanut plantings in that State.

The relative returns for rice cultivation in the various States do not substantiate the hypothesis. This is probably due to the special place of rice cultivation in agricultural frontier areas. The comparative advantage of rice in these areas is due to traditional methods of farming newly cleared land which favor certain crops, such as rice and cotton, and the richness of the virgin soils. The high yields from these virgin soils were also apparently a principal factor causing the shift of coffee production from Sao Paulo to Parana. 17/

Rice was the principal crop in the first stage of agricultural expansion in the Minas Triangle and Goias. Rice cultivation pays for the clearing of new land which is eventually used for pasture. In return for clearing a given piece of land, workers are allowed to plant rice and subsistence crops for their own use for approximately 2 years. After this period, the workers are required to plant pasture on the land for the landlord's use (118, July-August, 1971; 50, p. 157). Rice cultivation is also used to renovate exhausted pastures in these areas. (Cotton is used for much the same purpose in frontier regions of Parana (69, p. 7)).

Rice also served a valuable role when coffee was first planted in the frontier of northern Parana. During the 3 or 4 years before the coffee "trees" reached maturity, rice or corn and beans were grown between the rows of "trees." These interplanted crops compensated the workers who established the coffee plantations (36, p. 71; 84, part I, p. 39; 59, p. 65).

Labor Costs--The last major factor involved in the changing nature of Sao Paulo crop production was the shift toward less labor-intensive crops, such as sugarcane, corn, and soybeans, and away from those that require more labor, particularly coffee and cotton. Farm labor legislation brought rural wage rates, benefits, and employment security up to the urban level in 1964. Because most of Sao Paulo's commercial agricultural production originates on large farms heavily dependent on hired labor, this legislation accelerated the trend toward crops which were adaptable to mechanized farming methods. Government policy favoring farm mechanization through credit and tax incentives has accelerated this trend. Thus, commodities less adaptable to mechanized farming, particularly coffee, are now relatively more expensive to produce than before the introduction of policies which had the effect of raising labor costs and lowering machinery costs.

17/ The importance of higher yields in agricultural frontier areas as a factor causing shifts in land use is discussed by Herrmann (35, pp. 29-33).

LABOR AND MECHANIZATION

The Labor Force

In 1970, only 20 percent of Sao Paulo's population lived in rural areas. A much larger proportion of Brazil's total population is rural, but urbanization has been developing rapidly, in both Sao Paulo and the rest of Brazil. 18/ The decline in rural population, as a percentage of the total, is shown below:

Year	Brazil	Sao Paulo
	Percent	
1950	64	47
1960	55	37
1970	44	20

Source: Census of Population, reported in (93, 1971).

The percentage of the population directly dependent upon agriculture is somewhat smaller than the rural population (74, pp. 109-110).

The number of Brazilians employed in the agricultural sector increased by approximately 45 percent between 1950 and 1970. In Sao Paulo, however, employment in agriculture has been declining:

Year	Workers in agriculture in--		Sao Paulo's share
	Brazil	Sao Paulo	
	- - - - Thousands - - - -		Percent
1950	1/ 12,614	1/ 1,708	14
1960	15,634	1,727	11
1970	18,246	1,513	8

1/ Adjusted for undernumeration in the 1950 Census of Agriculture.

Source: (24, 35, p. 36).

18/ Rural areas are defined as those lying outside the cities (the equivalent of county seats) and towns (seats of districts, which are municipio subdivisions).

This decline has occurred despite heavy immigration from other parts of the country--particularly from Minas Gerais and the Northeast--which helped to boost Sao Paulo's population from 9 million in 1950 to 18 million in 1970.

In Brazil

There are many different types of farmers and farmworkers in Brazil. Several important types are as follows:

(1) Owners of large farms who usually employ others in their farming operations.

(2) Small-scale owners who operate their farms with the assistance of family labor. The best examples of this type of farmer are the descendants of 19th century immigrants from Central European countries in Santa Catarina and Northern Rio Grande do Sul and the descendants of Japanese immigrants who farm all over Brazil, but who are most heavily concentrated in parts of Sao Paulo.

(3) Subsistence-type owners and squatters who farm small properties that do not provide adequate family incomes. These farmers and their families usually provide a source of labor for larger neighboring farms.

(4) Large-scale tenant farmers who use a package of modern inputs. These farmers are most prevalent in the rice and wheat-soybean areas of Rio Grande do Sul (42, pp. 38-41).

(5) Agricultural workers who have limited rights to the land, such as small tenants, sharecroppers, colonos (coffee workers), 19/ and moradores. Small tenants operate with varying degrees of independence, while sharecroppers generally have more responsibilities but fewer risks than tenants. In most cases, production decisions on tenant and sharecrop farms are made by the landowner (38, pp. 195, 196, 218, 220, 228). Colonos, found mostly in Parana, Sao Paulo, and Minas Gerais, are paid a fixed amount of cash for the coffee they care for and harvest and are provided with a plot for growing subsistence crops. Moradores receive a plot for subsistence crops in return for a specified amount of unremunerated work for the landowner. These workers are most common in the Northeast.

(6) Nonresident day workers (volantes) who have no rights to the land. These workers are paid in cash by the day and are usually associated with fulfilling labor needs during peak demand periods on large mechanized farms.

(7) Salaried workers. These workers are usually associated with cattle production or mechanical work (for example, tractor operators). Farm administrators are also included in this category.

The distinctions between the types of farmers and farmworkers described above are not always clear, for many farmers are involved in more than one type of work or may switch from one type of work to another.

In Sao Paulo

Although all types of farmers and farmworkers described above are found in Sao Paulo, the State differs somewhat from the rest of the country in that a higher

19/ These colonos should not be confused with the small-scale owners in Santa Catarina and northern Rio Grande do Sul who are also referred to as colonos.

proportion of its large farm owners are considered to be efficient operators, 20/ and there is a greater percentage of nonresident day workers.

Types of farmworkers in Sao Paulo changed radically over the past decade, as shown in the following tabulation:

Type of farmworker 1/	1960	1969
	1,000	
Owners 2/	378	454
Tenants	230	83
Sharecroppers	288	254
Colonos	229	32
Salaried workers	79	NA

1/ Women working part-time and children under 15 are counted as one-half unit.
2/ Includes large landowners as well as small subsistence-type farmers.

Sources: Data collected by IEA and reported in (75, p. 30; 63, p. 221).

The number of tenants and colonos declined drastically, but the number of nonresident day workers or volantes increased. A survey in 1970 recorded 350,000 volantes, compared with 226,000 in 1964. The major factors responsible for these changes were: (1) changes in the relative importance of the State's principal agricultural commodities, especially the decline in coffee production (which is very labor-intensive); (2) the increased use of mechanized methods; and (3) labor legislation enacted in 1963, which by granting increased benefits to resident farmworkers, encouraged substitution of contracted day laborers for resident workers (63, pp. 97-98, 219-221; 74, p. 115; 57, p. 385; 38, p. 212; 68).

Labor Productivity

It is difficult to measure the output of agricultural labor in Brazil, largely because of the unavailability of statistics on the farm value of meat production. However, an indication of changes over time and comparisons between regions of per worker output can be obtained by calculating the per worker share of the farm value of the most important crops and milk and eggs. Cropland per worker and cows per worker can also be used to indicate the level of productivity. These indicators are listed in table 12.

Whether measured in terms of value of crops, milk, and eggs, or just value of crops, Sao Paulo's output per farmworker in 1970 was more than 2.5 times greater

20/ The 1967 cadastral survey (see page 19) identified 8.4 percent of Sao Paulo's farms, accounting for 19.6 percent of the State's farmland, as "rural enterprises," compared with 1.9 percent of Brazilian farms, or 3.6 percent of the nation's farmland. In the second ranking States, Parana and Espirito Santo, 3.1 percent of the farms were classed as "rural enterprises."

Table 12--Indicators of labor productivity in Brazil and Sao Paulo, 1950-70

Item	Brazil	Sao Paulo
	1965-67 cruzeiros 1/	
Output per worker:		
24 crops, 2/ milk, and eggs:		
1960	456	1,014
1970	489	1,313
24 crops 2/:		
1960	386	838
1970	402	1,058
	Hectares	
Cropland per worker:		
1950	1.5	2.5
1960	1.8	2.8
1970	1.9	3.2
	Number	
Cows per worker:		
1950	3.7	3.4
1960	5.0	5.3
1970	5.4	7.6

1/ Prices adjusted by price index no. 2 of the Getulio Vargas Foundation.
2/ As reported in Anuario Estatistico, pineapple, cotton, peanuts, rice, bananas, sweet potatoes, potatoes, cocoa, coffee, sugarcane, onions, coconuts, beans, tobacco, jute, oranges, castor beans, manioc, corn, sisal, soybeans, tomatoes, wheat, and grapes.

Sources: (13, 14, 24, 35, 93).

than that for all of Brazil. The amount of cropland and the number of cows per worker were also substantially greater in Sao Paulo. The gap in worker productivity between Sao Paulo and Brazil as a whole is apparently widening. Between 1960 and 1970, the per worker value of crop, milk, and egg production increased by 29 percent in Sao Paulo and only 7 percent in all of Brazil. The amount of cropland and the number of cows per worker has also been increasing at a faster rate in Sao Paulo. Since 1960, labor productivity in Sao Paulo has apparently increased only on large farms of 50 hectares and more:

Farm size	Cropland per worker	
	1960	1970
	Hectares	
0 - 49 hectares	2.1	2.1
50 - 999 hectares	3.5	4.8
1,000 and more hectares	3.5	6.1
Total	2.8	3.2

Source: (14, 24).

Much of the difference between the labor productivity figures for Sao Paulo and Brazil is due to the heavy weight of the very poor Northeast region on the latter. However, farm labor productivity in Sao Paulo is substantially higher than that of other productive States in the southern half of the country. For instance, the value of 1970 output of crops, milk, and eggs per worker was 53 percent higher (38 percent considering only crops) in Sao Paulo than in Rio Grande do Sul, which is usually considered to have one of the most developed agricultural economies in the nation.

The work of William Nicholls and Ruy Miller Paiva points out the large differences in labor productivity between Brazilian farms in the Northeast and the Center-South. In 1963, they analyzed the output of 99 Brazilian farms in seven States--about half in the Northeast and half in the Center-South. For their sample of farms, the value added per man-year of labor was $631 in the Center-South versus only $183 in the Northeast. Although the Center-South farms produced 3.4 times as much per worker as the Northeast farms, their output was still only one-eighth the output of U.S. farmworkers in 1963 (57, pp. 383-384).

A more exact picture of labor productivity in Sao Paulo can be obtained by using estimates of total agricultural output published by the State's Instituto de Economia Agricola. According to these data and Census of Agriculture employment data, output per worker employed in agriculture in Sao Paulo was:

Year	Constant 1969 dollars per worker 1/
1950	550
1960	676
1970	2/ 937

1/ Constant 1969 cruzeiros converted to dollars at rate of 4.138 cruzeiros per dollar.
2/ Equivalent to approximately 1,450 cruzeiros of 1965-67.

Source: (74, p. 70; 14; 24; 35, p.36).

These estimates indicate an even more rapid rate of increase in Sao Paulo's agricultural labor productivity than is shown in table 12. The average annual growth rates implied are 1.8 percent for 1950-70, 1.4 percent for 1950-60, and 2.3 percent for 1960-70.

The superior output of Sao Paulo's agricultural labor relative to the rest of Brazil is undoubtedly due in part to the State's soil and climate, which are favorable to agriculture, and to a crop mix weighted heavily by high-value commodities like coffee, sugar, and oranges. However, the major factor is probably the greater use of labor-saving machinery in Sao Paulo.

Agricultural Mechanization

Growth of Mechanization

Brazilian agriculture has been mechanizing at a rapid rate in recent years. The total number of tractors on farms increased 148 percent between 1960 and 1970

(table 13). 21/ By early 1973, an estimated 200,000 tractors were being used for agricultural purposes, 28 percent more than in 1970. Nevertheless, farm machinery in Brazil is the exception rather than the rule. In 1970, there was only one tractor for every 32 farms or one tractor for every 218 hectares of cropland in Brazil, compared with more than one tractor on each farm and one tractor for every 61 hectares of cropland in the United States. In the same year, there were 117 Brazilian farmworkers for every tractor available, compared with less than one worker for every tractor in the United States. Of the 25 States and territories in Brazil, only three States (Sao Paulo, Rio Grande do Sul, and Parana) accounted for 80 percent of the farm tractors. Less than 5 percent of the tractors were in the north and northeastern parts of the country. This regional disparity shows up in the Nicholls-Païva study of 99 farms throughout Brazil in 1963. It showed that investment in machinery amounted to $115 per worker in two areas of the semiarid Northeast, compared with $841 in four areas in the Center-South (56, p. 227).

Table 13--Indicators of agricultural mechanization in Brazil and the United States, 1950, 1960, and 1970

Region	Tractors 1/	Cropland per tractor	Farmworkers per tractor	Farms per tractor
	Number	Hectares	Number	
Brazil:				
1950	8,372	2,281	1,507	247
1960	63,493	452	246	53
1970	156,592	218	117	32
Sao Paulo:				
1950	3,819	1,115	447	58
1960	28,101	170	61	11
1970	65,731	73	23	5
Rio Grande do Sul, 1970	42,121	119	35	12
Parana, 1970	16,537	287	121	34
Rest of Brazil, 1970 2/	32,203	608	411	110
United States, 1970	4,770,000	61	0.9	0.6

1/ Probably includes motorized cultivators and minitractors in Brazil.
2/ Brazil, less Sao Paulo, Rio Grande do Sul, and Parana.

Sources: (12, 14, 24, 102).

In 1970, 42 percent of Brazil's tractors was in Sao Paulo. Sao Paulo had 23 workers per tractor and five farms per tractor, a much higher rate of mechanization than in Brazil as a whole and also substantially higher than other States (Rio Grande do Sul and Parana) that were relatively highly mechanized (table 13). Although the table indicates that Sao Paulo was not far behind the United States in hectares per

21/ During the same period, cropland increased approximately 37 percent, and farm employment, 17 percent.

tractor, the efficiency of tractor use must be substantially different in the two areas as indicated by the much greater number of workers per tractor in Sao Paulo.

Production of Farm Machinery

Since 1960, most of the growth in Brazil's tractor fleet has come from domestically manufactured machines (table 14). Tractor production in Brazil was initiated in 1960, increased rapidly through 1964, stagnated between 1965 and 1969, and thereafter, began increasing at a rapid rate. The poor sales period of 1965-69 has been attributed to high taxes and increasing real interest rates. Tax exemptions and easier financing boosted tractor sales beginning in 1970 (109, Feb., 1973; 112, Jan.-Feb., 1972). Since the establishment of a domestic tractor industry, only those types of tractors not manufactured in Brazil, mostly high-horsepower models, have been allowed to be imported. In 1973, Sao Paulo's farmers purchased 37 percent of domestically produced tractors.

Table 14--Imports, exports, and domestic production of wheeled tractors for use in agriculture, Brazil, 1951-73 1/

Year	Imports	Exports	Production	Total availability
		Units		
1951	10,967	0	0	10,967
1952	7,363	0	0	7,363
1953	2,698	0	0	2,698
1954	14,147	0	0	14,147
1955	5,345	0	0	5,345
1956	5,056	0	0	5,056
1957	6,810	0	0	6,810
1958	7,135	0	0	7,135
1959	4,579	0	0	4,579
1960	12,702	0	37	12,739
1961	6,382	0	1,679	8,061
1962	1,714	0	7,586	9,300
1963	1,330	0	9,908	11,238
1964	1,341	2	11,537	12,876
1965	374	3	8,121	8,492
1966	639	6	9,069	9,702
1967	342	31	6,223	6,534
1968	990	36	9,818	10,772
1969	423	16	9,548	9,955
1970	60	41	14,029	14,048
1971	184	104	22,122	22,202
1972	228	188	29,142	29,182
1973	NA	327	37,170	NA

NA = not available.

1/ Does not include power cultivators or minitractors.

Source: (96, 119, 93).

Domestic production of combine harvesters began in the late 1960's, and by 1972, output had reached approximately 3,500 units (report from U.S. Agricultural Attaché). Power cultivators and minitractors are also manufactured in Brazil; 7,041 were produced in 1973. Most of these machines are used in Sao Paulo by horticultural farmers of Japanese descent (5, p. 171; 69). The manufacture of tractor implements began in Brazil in 1954 but didn't really get off the ground until the domestic tractor industry was established in 1960 (112, Jan.-Feb., 1972).

Utilization Patterns

Use of mechanical power was not very widespread on Brazilian farms in 1960 (table 15). Even in Sao Paulo, only 6 percent of all farms used some mechanized equipment. However, when only large farms (50 or more hectares under cultivation) are considered, the picture changes considerably. For all of Brazil, over a quarter of these farms were at least partially mechanized in 1960, and in Sao Paulo over half were mechanized. Between 1950 and 1960, the percentage of large farms relying on animal power declined sharply, while those relying on human power increased somewhat. This phenomenon was probably due to farms switching from animal power to mechanical power, and to large numbers of new farms in frontier areas, where reliance on human labor is high.

Table 15--Source of power used on farms in Brazil and Sao Paulo, 1950 and 1960

Region and source of power	All farms		Farms with 50 or more hectares under cultivation	
	1950	1960	1950	1960
	Percent			
Total Brazil:				
Human	73	76	34	45
Animal	27	23	55	27
Mechanical 1/	--	1	11	27
Sao Paulo:				
Human	46	43	15	16
Animal	53	51	69	32
Mechanical 1/	1	6	16	52

-- = less than 0.5 percent.

1/ At least some mechanized equipment used.

Source: (12, 14).

An indicator of high reliance on animal and machine power as opposed to unaided human effort is the number of hectares of annual cropland per plow:

Region	Hectares per plow in 1960
Brazil	20
North and Northeast	316
Center-South	14
Sao Paulo	11
Rio Grande do Sul	8

Source: (14).

The greatest reliance on unaided human power in crop production was in the Northeast. Within the Center-South, the greatest use of plows was in Rio Grande do Sul, Santa Catarina, and Sao Paulo. The least favorable ratio of plows to annual cropland in Brazil was in the frontier State of Maranhao, where the ratio was 1 plow to 7,331 hectares.

The rapid pace of mechanization in Sao Paulo during the 1960's is shown in statistics collected by the IEA: Of all plowed land in the State, the percentage prepared with tractors increased from 53 to 70 percent between 1963 and 1968 (74, p. 141).

Tractor-pulled equipment in Brazil is used mainly for land preparation--plowing and grading--and very little for other operations. This is verified by a recent estimate of tractor implements as a percentage of tractors in Brazil:

Tractors	100
Plows	90
Harrows and rakes	80
Seeders	15
Reapers	15
Cultivators	12

Source: (5, p. 172).

Sao Paulo's Instituto de Economia Agricola notes that use of machinery in Sao Paulo's agriculture has increased much more slowly in planting and cultivating operations than in soil preparation. Mechanized harvest operations are said to be practically nil because in most cases, harvesting machinery is too costly to compete with relatively cheap labor (74, p. 140). However, there are indications that the situation has begun to change (119).

The reasons for this imbalance in tractor use, other than the cost factor, are probably the nature of the operations involved and the necessity of maintaining a large labor force for periods of peak agricultural activity. Soil preparation occurs at a time of peak labor demand, and proper timing is important. On sharecropped farms, the farm owner is often responsible for soil preparation--a factor favoring the mechanization of only this one operation.

Factors Influencing Mechanization

Farm Machinery Prices--In real terms, farm machinery prices in Sao Paulo tended to decline during 1961-72 after having risen sharply during 1953-60 (table 16).

Table 16--Index of real prices for farm machinery and equipment in Sao Paulo in terms of money and prices received by farmers for agricultural commodities, 1950-72

Year	Real money price	Index of farm machinery and implement prices ÷ index of prices received				
		21 commodities	Cotton	Corn	Rice	Sugarcane
		1948-52 = 100				
1950	99	91	109	134	129	93
1951	94	91	72	109	152	100
1952	95	93	108	85	86	106
1953	109	100	154	94	61	133
1954	122	106	163	163	88	134
1955	125	114	152	101	107	134
1956	125	120	169	113	95	115
1957	128	131	164	133	98	128
1958	133	158	175	128	92	162
1959	145	177	204	130	127	177
1960	148	166	172	192	153	161
1961	139	153	148	124	162	158
1962	139	140	176	136	87	146
1963	135	138	188	180	81	102
1964	123	118	156	127	113	87
1965	131	154	172	177	202	103
1966	115	132	186	146	101	117
1967	114	148	193	165	103	123
1968	113	149	177	202	107	127
1969	120	138	194	146	133	138
1970	110	122	183	159	153	136
1971	NA	NA	NA	NA	NA	NA
1972	110	NA	143	151	98	133

N A = not available.

Source: Calculated from (74, 119).

Machinery prices also trended downward in terms of prices of 21 principal agricultural commodities. When measured in terms of individual crop prices, there is no apparent relationship between time and machinery prices, except for sugarcane in 1965-69, when machinery prices increased.

In terms of money, and in terms of the amount of corn or rice needed to purchase a tractor, there was little difference between tractor prices in the United States and Sao Paulo during 1966-71 (table 17). 22/ In terms of cotton needed to purchase a tractor, the Sao Paulo price was substantially higher than the U.S. price. By early 1974, the inflation-adjusted price of tractors in Sao Paulo was slightly below the 1971 level, but the price in terms of agricultural commodities declined substantially during 1971-74 (119).

Table 17--Prices paid for tractors (40-50 horsepower range), United States and Sao Paulo, 1966-71

Year	Cost in money		Cost in amount of produce needed to purchase a tractor					
			Seed cotton		Corn		Rice	
	U.S. 1/	S.P. 2/	U.S.	S.P.	U.S.	S.P.	U.S.	S.P.
	Dollars per unit		Tons of produce					
1966	4,426	4,785	20	37	108	115	41	43
1967	4,570	4,983	19	39	113	82	42	44
1968	4,746	4,637	22	35	112	159	43	44
1969	4,858	4,586	25	35	107	109	45	50
1970	4,975	4,085	23	30	95	102	44	53
1971	5,179	4,918	19	28	122	116	45	44

1/ Average of prices paid for tractors of 30-39 hp. and tractors of 50-59 hp.
2/ Cruzeiros converted to dollars at the following rates (cruzeiros per dollar): 1966 - 2.222, 1967 - 2.715, 1968 - 3.492, 1969 - 4.138, 1970 - 4.680, 1971 - 5.383.

Sources: (104, 90, 74).

Tax exemptions for tractor production and sales accounted for the large declines in the real money cost of tractors in Sao Paulo in 1968 (7 percent) and 1970 (11 percent). Tractor producers were exempted from the Industrial Products Tax (IPI) in October 1967, and sales of tractors were exempted from the Value Added Tax (ICM) 23/ in December 1969. Tractor sales increased sharply in the years following the granting of these exemptions. Another factor which has recently lowered farmers' real price of tractors and other agricultural machinery is the income tax deduction that can be made for these investments (112, Jan.-Feb., 1972; 5, p. 172).

Credit--Easy credit terms offer a powerful incentive for agricultural mechanization in Brazil. Currently, banks in the Center-South will finance tractor purchases for 4 or 5 years with 1 year's grace, and 15 percent per annum interest with no

22/ Corn and rice yields in Sao Paulo are substantially lower than in the United States, so the U.S. farmer does have an advantage in terms of hectares of produce needed to purchase a tractor.
23/ Imposto de Circulacao de Mercadorias. It is levied by the States and ranges from 15 to 18 percent. For a full description see (34).

additional payments for monetary correction. 24/ Usually 80 percent of the purchase price is financed, but it is possible to obtain a tractor with no down payment at all. In the Northeast, the repayment period is 7 years, with a 2-year grace period and only 7-percent interest. During the mid-1960's, increasing real interest rates and shorter repayment periods adversely affected tractor sales. The improved financing terms were reportedly a significant factor in the improved sales in 1970 and thereafter (U.S. Agricultural Attaché, BB-3001, Jan. 22, 1973; (112, Jan.-Feb., 1972; 109, Feb., 1973).

Farm Labor.--The rural labor law, which has been in force since 1964, requires employers of farm labor to pay the same minimum salaries as required in urban areas and to grant numerous social benefits to permanent employees. The enactment of this law coincided with an increase in farm salaries in Sao Paulo. Labor shortages in the farm sector have since placed continued pressures on farm labor costs (69). The following tabulation shows the growth in real daily wages of resident farmworkers in Sao Paulo:

Year	Index of real wages 1/
	1948-52 = 100
1953-57	97
1958-62	86
1963	75
1964	84
1965	95
1966	90
1967	98
1968	104
1969	102
1970	113
1971	117
1972	130
1973	155

1/ Deflated by index No. 2, Getulio Vargas Foundation.
Source: Calculated from (119).

The rural labor law, by requiring social benefits for permanent workers, discouraged the practice of keeping large permanent work forces on farms and thus contributed to pressures to mechanize agricultural operations. A Sao Paulo newspaper article noted that the labor laws caused a disinterest in activities requiring large amounts of manpower and were thus a factor behind the introduction of soybeans (a highly mechanized crop in Brazil) into Sao Paulo (124, Mar. 4, 1973).

24/ That is, there is no adjustment for inflation, which means the real interest rate is close to zero.

Changing crops.--Since the late 1950's, there has been a sharp decline in Sao Paulo's coffee area and a corresponding increase in the area of sugarcane and annual crops. In 1955-59, 32 percent of Sao Paulo's cropland was in coffee and 65 percent in sugarcane and annuals. By 1965-69, only 12 percent was in coffee and 84 percent in sugarcane and annuals (table 7, page 21). The latter crops are much more susceptible to mechanized production methods than coffee.

Regions and Crops Affected

In 1970, the greatest degree of farm mechanization in Sao Paulo was in the area surrounding the city of Sao Paulo and in the eastern and northern parts of the State. The areas most highly mechanized in terms of the fewest farms per tractor and fewest workers per tractor corresponded fairly closely to Sao Paulo's principal sugarcane-producing areas and to the areas of Terra Roxa soil. The 1970 level of mechanization in Sao Paulo's four geographic regions was:

Region	Cropland per tractor	Farms per tractor	Workers per tractor
	Hectares	Number	
Atlantic Coast	101	11.4	43
Atlantic Highlands	34	5.1	23
Paleozoic Depression	65	4.1	17
Western Plateau	87	5.0	24

Source: Calculated from (24).

Commodities associated with mechanized farming in Sao Paulo are sugarcane, soybeans, rice, cotton, and corn. A 1972 study claimed that the planting and cultivating of sugarcane and soybeans were more mechanized than for other crops in the State. For the other crops, animal power reportedly remained more important than mechanical power (74, p. 140). One of the reasons for the high level of mechanization on the sugarcane farms is that one-half of the State's sugarcane land is on large estates directly controlled by the sugar mills. An apparent result of the mechanization is lower labor requirements. In 1965, labor requirements for producing sugarcane in Sao Paulo were only 43 percent of those in the northeastern State of Pernambuco (1, p. 28). Sao Paulo's soybean production, which is concentrated on large farms, is almost completely mechanized.

A 1967 study of rice producers in Sao Paulo's largest rice-producing municipality, Guaira, showed a high rate of mechanization.

Item	Respondents using mechanized methods	
	Number of farms	Area
	Percent	
Soil preparation	88	98
Cultivation	40	61
Harvest	70	84

Source: (47, p. 18).

Mechanized land preparation is common in cotton production, but harvesting is still mainly a hand operation. However, since 1971, several cotton-picking machines have been imported, mainly for use in Sao Paulo, southern Goias, and the "Triangle" of Minas Gerais (70).

The corn situation is similar to that of cotton. Mechanized procedures are widely used on large commercial farms for soil preparation, but mechanical harvesting is extremely rare. In 1969, it was estimated that less than 5 percent of Brazil's corn was harvested by mechanical pickers (80, p. 14).

Other parts of Brazil with levels of farm mechanization comparable to those in Sao Paulo are limited. In 1970, the areas with the greatest degree of farm mechanization, outside of Sao Paulo, were southern and central Rio Grande do Sul, parts of Santa Catarina and Parana, the "Triangle" area of Minas Gerais, southern Mato Grosso, parts of Rio de Janeiro State, and the areas near a few large cities.

Outlook

Mechanized farming methods have apparently been a contributing factor to the rapid expansion of Brazilian agriculture in recent years. The production of wheat and soybeans, the two crops whose output has increased at the fastest pace, is heavily dependent upon mechanized methods. Mechanized farming has also been important in the rapid growth of crop production in the Center-West frontier areas. Sao Paulo, the State with the highest level of mechanization in Brazil, is also one of only two States where the absolute number of workers declined between 1960 and 1970. 25/

The gap between the level of mechanization in Sao Paulo and other States indicates a large potential for further mechanization. In addition, the large number of workers per tractor, even in Sao Paulo, indicates a potential for intensifying the use of machinery now available.

CROP YIELD IMPROVEMENTS

Yields in Sao Paulo and Brazil, 1950-73

Crop yields in Sao Paulo have tended to increase faster than yields in other Brazilian states. Herrmann found that for 1947-65, yields in Sao Paulo 26/ rose at a rate of 0.8 percent per year, compared with a rate of 0.1 percent for all of Brazil. Only Amazonas and Maranhao had higher rates (35, p. 31). Between 1960-62 and 1968-70, Sao Paulo's crop yields increased at an annual rate of 1 percent, while Brazilian crop yields showed no change 27/. The Sao Paulo yield improvements are most likely due to increased use of fertilizers, pesticides, and improved seeds.

25/ The other State is Pernambuco.

26/ Total output (value of production calculated with 1957-59 average prices) divided by total input (area planted to crops).

27/ The value of 24 crops was divided by area in those crops for the indicated years. Unit values for 1960-62 were used.

Yield increases for some specific crops in Brazil and Sao Paulo are compared in table 18. The table includes commodities that are important in both Sao Paulo and the rest of Brazil. Yield improvements in Sao Paulo were superior to those in Brazil as a whole for coffee, corn, cotton, and oranges. Declines in rice and bean yields in Sao Paulo were due to production shifts to marginal lands and the low level of technology generally used in bean and dryland rice production.

For most improtant commodities, crop yields in Sao Paulo are higher than or equal to those in the rest of Brazil (table 19). For example, yields of corn, cotton, manioc, sugarcane, and tomatoes are substantially higher.

Table 18--Changes in crop yields in Brazil and Sao Paulo, 1950-54 to 1966-70

Crop	Brazil	Sao Paulo
	Percent change	
Coffee	+ 125	+ 172
Sugarcane	+ 26	+ 19
Corn	+ 14	+ 29
Cotton	+ 10	+ 86
Rice	- 2	- 10
Beans	- 2	- 17
Oranges	- 5	+ 19

Source: Calculated from (93).

Table 19--Crop yields in Sao Paulo compared with total Brazilian crop yields, 1965-69, 1970 and 1971

Crop	Yield in Sao Paulo as a percent of Brazilian yield		
	1965-69	1970	1971
Bananas	81	80	77
Beans	90	101	91
Coffee	106	122	124
Corn	119	135	119
Cotton	140	151	143
Manioc	132	129	128
Oranges	96	97	100
Peanuts	99	102	95
Potatoes	128	103	121
Rice	82	99	79
Soybeans	121	127	96
Sugarcane	122	125	119
Tomatoes	138	122	121
Wheat 1/	105	86	101

1/ Crops harvested 1964-68, 1969, and 1970.
Source: Calculated from (93, 95) except cotton for total Brazil, which was calculated from estimates of the Foreign Agr. Serv., U.S. Dept. of Agr.

In fact, among the more important commodities, only rice yields come out unfavorably when compared with yields in all of Brazil, and this is partly due to the weight of higher yielding irrigated rice in Rio Grande do Sul. Rice yields in Sao Paulo are about the same as those in neighboring States where nonirrigated rice is grown.

Average yields of most commodities in Sao Paulo are low, however, when compared with yields in the United States. Table 20 shows that only cotton and soybeans have yields approaching those in the United States. (Cotton yields in Sao Paulo are very favorable when compared only with the yields in Texas). Sao Paulo corn yields are only about one-third of U.S. yields. The data on rice yields are not comparable because most of Sao Paulo rice is dryland and all U.S. rice is irrigated.

Fertilizer and Lime

Most Sao Paulo soils are deficient in nitrogen and phosphorus, and almost half of the cultivated area is excessively acidic and requires application of lime (page 7). Research on yield response of Brazilian crops to fertilization is apparently limited in its extent and usefulness (86, pp. 109-111; 43, p. 7), but many studies in both laboratory and field conditions have shown that yields in Sao Paulo and the rest of Brazil can be increased through the use of fertilizer 28/. However, the

Table 20--Crop yields in Sao Paulo compared with U.S. yields

Crop and location	1965-69	1972	1973
	Kilograms per hectare		
Corn:			
Sao Paulo	1,681	2,000	1,998
United States	4,858	6,093	5,730
Cotton (lint):			
Sao Paulo	401	346	458
United States	539	568	581
Texas	430	457	483
Mississippi	693	672	723
Rice (paddy):			
Sao Paulo	883	1,312	1,121
United States	4,363	5,896	5,384
Peanuts (in shell):			
Sao Paulo	1,225	1,280	1,231
United States	1,937	2,473	2,605
Soybeans:			
Sao Paulo	1,341	1,748	1,650
United States	1,736	1,870	1,868

Source: (102), appendix tables 1 and 2.

relatively high cost of fertilizer and the variable prices received for agricultural commodities (app. table 3) often restrict the use of fertilizer despite the higher yields.

Consumption, 1950-73

Apparent consumption of chemical fertilizers in Brazil is estimated by adding imports and domestic production. The lack of records prohibits the inclusion of inventory changes in the calculation. Also, there are no data on the use of organic fertilizer, but manure, coffee husks and pulps, and other processing byproducts are apparently widely used as fertilizing materials (11, p. 2; 59, p. 226; 25, p. 24).

Estimated consumption of chemical fertilizer nutrients 29/ in Brazil increased by more than 20 times between 1950 and 1973 (table 21). 30/ A rapid growth in consumption occurred in the late 1950's, followed by a stagnant period of no growth and another period of extremely rapid growth beginning in 1967. In 1973, Sao Paulo farmers consumed about 35 percent of the fertilizers used in Brazil, and applied more than 2 1/2 times as much fertilizer per unit of cropland as in Brazil as a whole. (By 1973, fertilizer application per hectare of cropland in Sao Paulo had reached an apparent level higher than the level of use in the United States (82). However, Sao Paulo's dominance of Brazilian fertilizer consumption has decreased in recent years because of the rapid increase in consumption elsewhere in the country, particularly for use on wheat in Rio Grande do Sul, where consumption increased 430 percent between 1967 and 1971.

A 1970 survey of 154 small, medium, and large farm operators in three municipalities 31/ of northern Sao Paulo found an almost universal acceptance of fertilizer usage. The proportion of farmers using fertilizer increased from less than one-half in 1960/61 to 97 percent in 1969/70 (table 22).

Although there are no statistics on the use of lime for agricultural p poses in Brazil, the production figures for ground limestone for agricultural purposes in Sao Paulo and some adjacent areas are available:

Year	1,000 metric tons
1964	342
1965	317
1966	352
1967	440
1968	604
1969	749
1970	832
1971	913
1972	1,023
1973	1,500

Sources: (74, p. 131; 119).

28/ See (35, p. 43; 47, pp. 21, 29; 86, p. 77; 107, July-August, 1968; 27; 112, July-August, 1972; 71; 28).

29/ Nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O).

30/ Apparent consumption data vary somewhat according to the source, but the relative magnitudes are similar regardless of the source.

31/ Municipalities (municipios) in Brazil are roughly analogous to counties in the United States.

Table 21--Apparent consumption 1/ of major fertilizer elements 2/ in Brazil and Sao Paulo, total and per hectare of cropland, 1950-73

Year	Total consumption		Sao Paulo's share	Consumption per hectare of cropland 3/	
	Brazil	Sao Paulo		Brazil	Sao Paulo
	1,000 metric tons		Percent	Kilograms	
1950	89	48	54	5.0	10.4
1951	121	71	59	6.8	15.9
1952	73	58	79	3.9	17.3
1953	117	65	56	6.1	14.0
1954	123	82	67	6.0	15.6
1955	161	106	66	7.5	20.3
1956	165	98	59	7.4	20.1
1957	207	121	58	9.1	25.4
1958	250	148	59	10.8	29.2
1959	226	136	60	9.3	27.8
1960	299	169	57	11.6	31.4
1961	248	154	62	9.3	28.4
1962	237	168	71	8.5	30.9
1963	314	192	61	10.7	33.7
1964	255	175	69	8.5	31.8
1965	290	176	61	9.1	30.6
1966	281	154	55	9.1	29.7
1967	448	220	49	14.0	42.2
1968	603	253	42	18.4	48.8
1969	627	320	51	18.5	63.8
1970	999	426	43	28.4	77.1
1971	1,126	504	45	30.4	88.1
1972 4/	1,447	595	41	37.3	106.6
1973 4/	1,899	670	35	46.8	130.1

1/ Imports plus domestic production.
2/ Nutrient weight of N, P_2O_5, and K_2O.
3/ Brazil, area in 24 crops according to IBGE (93). Sao Paulo, area in 17 crops according to IEA and IBGE (app. table 1).
4/ Data for 1972 and 1973 are based in part on estimates.

Sources: (63, p. 70; 119, 1974/75; 26).

Table 22--Utilization of chemical fertilizers by 154 farmers in 3 municipalities of northern Sao Paulo, 1960/61 to 1969/70

Crop year	Municipality of Guaira			Municipalities of Jardinopolis and Sales de Oliveira		
	Yes	No	No response 1/	Yes	No	No response 1/
	Percent					
1960/61	30	38	32	47	20	33
1963/64	48	28	24	54	14	32
1966/67	65	21	14	68	11	21
1969/70	96	3	1	98	2	0

1/ And "don't know."

Source: (53).

Production of lime for agricultural use quadrupled between 1964 and 1973 and more than met the estimated minimum needs of Sao Paulo's agriculture 32/. The principal problem encountered in expanding lime consumption in São Paulo is the high cost of transportation, for the limestone deposits are not in the western part of the State where the lime is in demand (114, March 10, 1969).

Factors Related to Changes in Consumption

Prices.--fertilizer prices, adjusted for inflation, tended to decline in the late 1950's, climbed steeply during 1960-65, and declined sharply during 1966-70 (table 23). The real price of fertilizer in 1970 was less than one-half of the 1965 price.

These trends in real fertilizer prices are similar when calculated in terms of farm commodity prices. A notable exception is that of coffee. Also, in the late 1960's, fertilizer costs did not decline as much in terms of sugar and cotton as they did in monetary terms.

Table 24 shows the Sao Paulo prices of selected nitrogen, phosphorus, and potassium fertilizer for 1966-69 and compares them with the prices of the same products in the United States. In monetary terms, Sao Paulo prices of all fertilizer products listed declined between 1966 and 1969, and by the latter year, were equal to or lower than the U.S. prices. Fertilizer prices in terms of cotton and rice also declined, but in terms of corn, there was no discernible trend, either up or down. However, because of lower commodity prices, São Paulo farmers in 1969 still needed more cotton or rice to buy a metric ton of fertilizer than U.S. farmers did.

Prices of fertilizer are generally lower in Sao Paulo than in other Brazilian States. This is probably because of the concentration of fertilizer manufacturing and mixing in Sao Paulo, the advantages of having over two-thirds of the country's fertilizer imports come through Sao Paulo's port of Santos, and the relatively extensive fertilizer distribution system in the State. The price advantage Sao Paulo farmers had in 1970 relative to farmers in other agriculturally important States is shown in table 25.

32/ A 1964 study (2, p. 296) estimated that to raise the pH of Brazilian acid soils by 1.0 would require the application of 3 tons of lime per hectare every 8 years. Assuming 2.9 million hectares of very acid cropland in Sao Paulo (58 percent of 5 million hectares (see p. 9), a minimum of 1.1 million tons of lime per year is required.

Table 23--Index of real fertilizer prices in Sao Paulo in terms of money and prices received by farmers for agricultural commodities, 1950-73

Year	Real fertilizer prices	Fertilizer price index by index of prices received					
		21 commodities 1/	Coffee	Sugar	Cotton	Rice	Corn
		1948-52 = 100					
1950	97	89	70	92	107	126	131
1951	96	93	86	102	74	155	112
1952	89	87	86	99	101	81	79
1953	72	66	64	88	102	40	62
1954	69	60	47	76	92	50	92
1955	82	75	67	88	100	70	66
1956	94	90	86	86	127	71	85
1957	69	70	70	69	88	53	72
1958	66	79	105	80	87	46	63
1959	50	61	96	61	70	44	45
1960	58	65	107	63	67	60	75
1961	84	92	156	95	89	98	75
1962	99	100	160	104	125	62	97
1963	100	102	141	75	139	60	133
1964	106	102	113	75	134	97	109
1965	124	146	218	98	163	191	168
1966	89	103	212	91	141	78	113
1967	73	95	166	78	124	66	106
1968	77	101	148	87	120	73	138
1969	74	85	101	85	119	86	90
1970	66	73	76	81	110	92	96
1971	69	NA	103	84	92	60	95
1972	73	NA	80	88	95	65	100
1973	82	NA	76	94	89	76	80

NA = not available.

1/ Includes livestock as well as crop commodities.

Source: Calculated from (74, 119, 98).

Table 24--Fertilizer costs in the United States and Sao Paulo, 1966-69

Product and year	Cost in money 1/		Cost in amount of produce needed to purchase 1 metric ton of fertilizer					
			Seed cotton		Corn		Rice	
	U.S. 2/	S.P. 3/	U.S. 2/	S.P. 3/	U.S. 2/	S.P. 3/	U.S. 2/	S.P. 3/
	U.S. $ per M.T.		Kilograms of produce					
Sulphate of ammonia:								
1966	58	82	274	641	1,422	1,972	533	734
1967	60	81	245	635	1,473	1,336	545	708
1968	59	66	279	496	1,397	2,212	539	622
1969	58	58	293	443	1,278	1,303	530	633
Triple superphosphate:								
1966	89	115	420	893	2,178	2,749	817	1,023
1967	93	100	381	782	2,286	1,646	846	872
1968	86	82	406	615	2,032	2,741	784	770
1969	82	71	412	545	1,802	1,602	747	778
Potassium chloride: 4/								
1966	61	83	285	644	1,478	1,982	555	738
1967	59	72	243	562	1,457	1,184	539	627
1968	54	56	254	421	1,189	1,875	491	527
1969	53	50	266	382	1,164	1,126	483	546

1/ Cruzeiros converted to dollars at the following rates (cruzeiros per dollar): 1966-2.222, 1967-2.715, 1968-3.492, 1969-4.138.
2/ Fertilizer prices on April 15.
3/ Annual average price.
4/ Muriate of potash.

Source: (104, 74, IEA data reported in 49).

Prices of ground limestone in Sao Paulo are not available, but the data in table 26 suggest some generalizations concerning Brazilian prices of ground limestone. Prices in terms of U.S. dollars are above U.S. prices in all regions except Goias. There is a great disparity of prices from State to State.

In addition to world prices, shipping costs, and manufacturing costs, import policies and taxes have influenced fertilizer prices. Brazil's import policy for fertilizers has changed abruptly from time to time over the past 20 years. Between 1953 and 1961, fertilizer imports were granted a very favorable exchange rate within Brazil's system of multiple exchange rates. In 1957, nonmixed fertilizers were made tariff exempt. During 1953-61, the domestic fertilizer industry was subsidized; fertilizer sales received exemptions from State and Federal taxes; and fertilizer was granted preferential rail freight rates and port fees. When the preferential exchange rate for fertilizers was abolished in 1961, fertilizer prices began a rapid climb (77, pp. 227-228; 76, pp. 295, 344; 25, p. 30; 11, p. 5).

Import duties were reimposed during the 1960's, but have since been liberalized. A system of flexible quotas now helps to protect domestic fertilizer manufacturers. By early 1972, most popular fertilizer imports were duty free or had an ad valorem duty of 1 percent. A few others had duties of 5, 10, or 15 percent (Dept. of State airgram A-65, Mar. 24, 1972).

Table 25--Annual average price of selected fertilizer materials in 6 Brazilian States, 1970

Fertilizer material	Sao Paulo	Pernambuco	Minas Gerais	Parana	Rio Grande do Sul	Goias
	Cruzeiros per metric ton					
Sulfate of ammonia	240	400	335	284	328	339
Calcium nitrate	248	1/230	NA	377	361	2/445
Natural phosphate	185	3/400	108	258	198	127
Simple superphosphate	209	4/240	294	248	261	260
Potassium chloride	281	338	344	289	337	441

NA = not available.

1/ 6 months only.
2/ 8 months only.
3/ Paraiba, 4 months only.
4/ Paraiba.

Source: (90).

Table 26--Average cost of ground limestone in the United States and 6 Brazilian States, 1966-73

Region	1966-70	1971	1972	1973
	U.S. dollars per metric ton 1/			
United States 2/. . .	5.32	5.90	6.14	6.76
Ceara	3/10.20	NA	19.00	20.10
Minas Gerais.	8.70	8.80	9.30	10.30
Rio de Janeiro.	14.00	11.60	13.90	15.10
Parana.	10.10	8.90	8.50	11.30
Rio Grande do Sul . . .	4/12.20	11.30	12.90	15.70
Goias	6.70	5.60	6.90	11.60

NA = not available.

1/ Dollars rounded to nearest $.10.
2/ Average of April 15 and Sept. 15 prices.
3/ 1968-70 only.
4/ 1967-70 only.

Source: (89, 90, 104).

Also, all "modern" agricultural inputs were exempted from the ICM (value-added tax) in late 1969.

Prices paid for fertilizer in Sao Paulo are apparently related to fertilizer use. Figure 7 compares an index of real prices paid for fertilizers and apparent use of fertilizer nutrients per cultivated hectare of land. Note that: (1) the decline in prices from 1957 to 1959 parallels the 1957-58 increase in fertilizer use; (2) the rapid price increases of 1960 to 1965 were accompanied by stagnation in use levels; and (3) the rapid increase in fertilizer applications beginning in 1967 follows by a year the beginning of a downward trend in prices. Larson and Cibantos examined changes in the consumption of fertilizer in Sao Paulo during 1949-71 and found price to be the only significant explanatory variable among those tested. (43, 26).

Credit availability.--The rapid increase in fertilizer use which began in 1967 is closely associated with increased availability and lower cost of credit for fertilizer purchases. Between April 1966 and July 1970, the FUNFERTIL program 33/ (partly financed by a U.S. Agency for International Development loan) allowed farmers to obtain interest-free loans for purchasing fertilizer and mineral supplements (for crops other than coffee, sugarcane, and cotton). The Government subsidized completely the normal interest rate of 17 percent. In July 1970, this program was replaced by FUNDAG 34/, a program which allowed for subsidized interest rates (borrower rate of 7 percent instead of 17 percent) on loans for purchasing a wide range of "modern" inputs, including fertilizer, mineral supplements, pesticides, certified seeds, and various inputs for livestock production. In real terms, a nominal interest rate of 7 percent is a substantial negative rate of interest when annual inflation is 15 or 20 percent (86, p. 105; 66, 6; 112, July-August, 1971).

Sao Paulo's Secretariat of Agriculture has a special program to expand the use of lime, which involves educational programs and 2-year, low-interest loans for the supervised application of lime. The implementation of this program in mid-1968 corresponded with a rapid increment in lime use (page 46) (74, pp. 131-132; 114, Mar. 10, 1969).

Research, extension, and promotion.--Sao Paulo's agricultural research and extension institutions, considered the best in Brazil, have been important factors in the State's relatively high rate of fertilizer use (77, p. 216). The body of research on fertilizer response in Sao Paulo and Brazil as a whole, however, is still quite limited. An ECLA (United Nations Economic Commission for Latin America) study in 1967 noted that much of the research on fertilizer use was limited in its usefulness because too few combinations of fertilizer use were tested and little attention was paid to the economic aspects of fertilizer usage (86, pp. 110-111). A 1964 study lamented that many research results were buried in files and never disseminated to those who could use them (2, p. 27).

Another important influence in the expansion of fertilizer is the promotional and research work of private fertilizer companies. Brazil's largest fertilizer manufacturer has established fertilizer mixing and distribution centers throughout the agricultural areas of Sao Paulo and neighboring States. Each center employs agronomists to take soil samples and tissue tests and to advise farmers on fertilizer use (114, March 10, 1969). In 1967, a group of Brazilian fertilizer companies formed

33/ Fundo de Estimulo Financiero ao Uso de Fertilizantes e Suplimentos Minerais.
34/ Fundo Especial de Desenvolvimento Agricola.

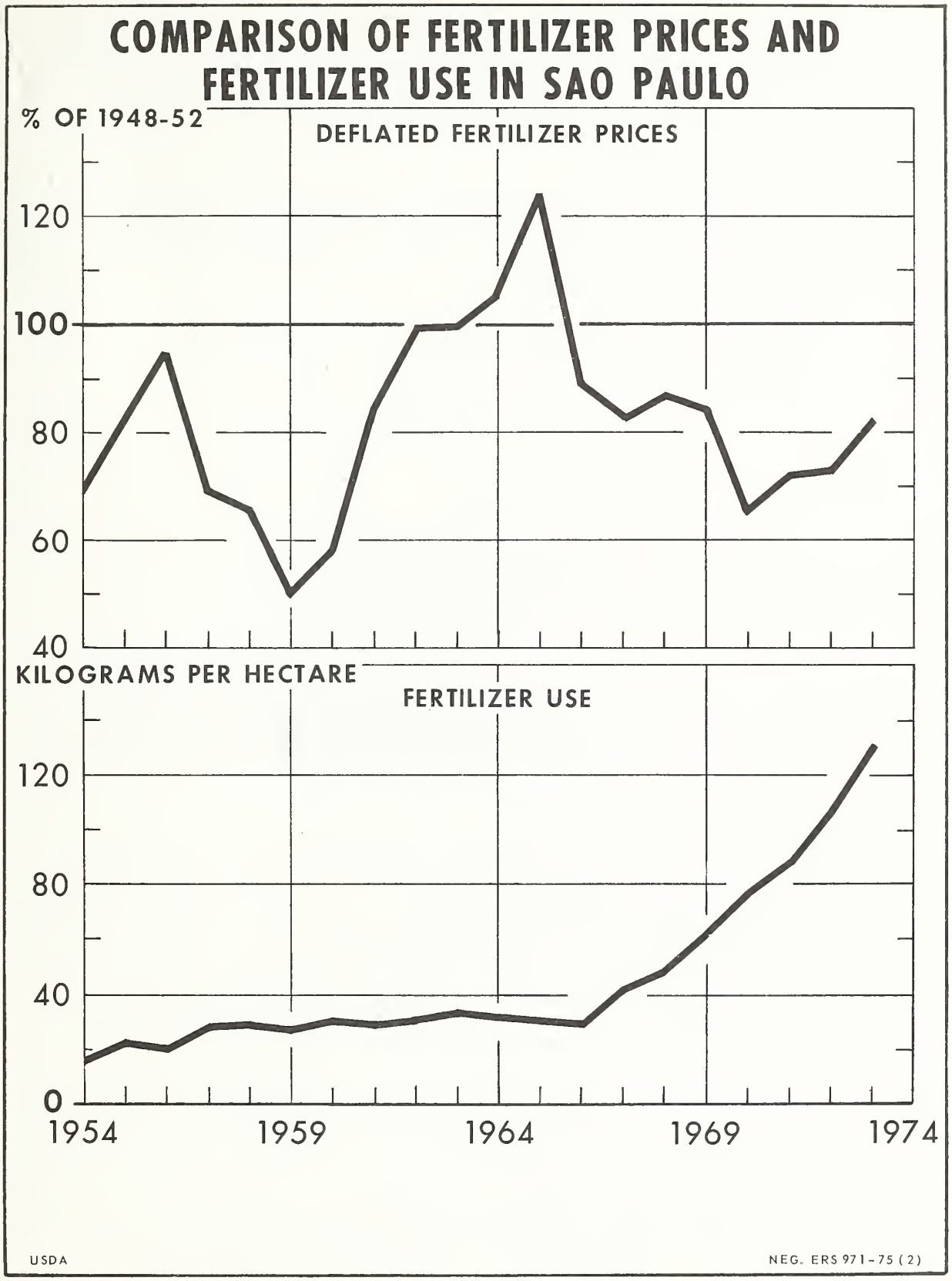
COMPARISON OF FERTILIZER PRICES AND FERTILIZER USE IN SAO PAULO
% OF 1948-52
DEFLATED FERTILIZER PRICES
120
100
80
60
40
KILOGRAMS PER HECTARE
FERTILIZER USE
120
80
40
0
1954
1959
1964
1969
1974
USDA
NEG. ERS 971-75 (2)

Figure 7

the National Association for the Promotion of Fertilizers 35/ which provides incentives for research on the economic use of fertilizers, divulges the results of such research, and advises the Government on the use of fertilizers in agricultural development projects. The fertilizer industry in Sao Paulo has had a similar Statewide trade group for some years (112, July-Aug. 1972, pp. 30-32; 63, pp. 106-107).

Consumption by Regions and Crops

In 1969, approximately two-thirds of Brazilian fertilizers was consumed in Sao Paulo and neighboring States (mainly Parana and Minas Gerais). The next largest consuming area was Rio Grande do Sul, Brazil's southernmost State. The following tabulation shows the percentage of fertilizer nutrient consumption of three major geographical regions of Brazil:

Region	1964	1971
	Percent	
North-Northeast	9	8
Central 1/	74	64
Extreme South 2/	17	28

1/ Southeast, Central-West, and Parana.
2/ Rio Grande do Sul and Santa Catarina.

Sources: (111, May, 1971; 112, July-Aug, 1972).

The extreme South's increasing share of consumption is due to the rapidly increasing acreage of wheat and soybeans (often double-cropped). In Rio Grande do Sul, close to 80 percent of the fertilizer consumed is used on wheat (usually double-cropped with soybeans) and another 15 percent is used on irrigated rice (U.S. agr. Attaché, Report BZ-1003, Jan. 26, 1971; 35, p. 42).

In the Northeast, most of the fertilizer is used on sugarcane and cocoa. within Sao Paulo, fertilizer use is fairly evenly distributed among the agricultural areas. The regions consuming the most fertilizer are those in the older farming areas in the eastern part of the State. 36/

The distribution of nutrient use by crops for the whole Central region is similar to that in Sao Paulo, which is shown in table 27. No records of fertilizer use are maintained in Brazil, and the figures in table 27 are estimates made by fertilizer importers, manufacturers, and mixers (49, pp. 113-124). (It is probably a slight exaggeration to list 100 percent of the cropland of various commodities as being fertilized).

35/ Associacao Nacional de Difusao de Adubos (ANDA).
36/ Particularly in the areas around the cities of Campinas, Piracicaba, and Ribeirao Preto.

Table 27--Estimated utilization of fertilizers by crops in Sao Paulo, 1969

Crop	Total fertilizer nutrients consumed	Total crop area fertilized
	Percent	
Coffee	1/30	18
Sugarcane	15	1/100
Cotton	9	48
Rice	9	32
Corn	8	12
Potatoes	8	100
Oranges	6	1/100
Tomatoes	5	100
Bananas	3	38
Vegetables	1/2	100
Peanuts	1	4
Onions	--	40
Strawberries	--	100
Others	2	10
Total	100	30

-- = zero or negligible.

1/ Estimates of fertilizer consumption by crops made by North Carolina State Univ. Internatl. Soil Testing Project in 1967 differ greatly for some crops from those shown here. The project's estimates show that coffee used only 15 percent of fertilizer consumed and was second to sugarcane in this respect and that vegetables consumed a quarter of all fertilizer, compared with the estimate of 2 percent shown here. The soil testing project also calculated that only 40 percent of the sugarcane acreage and 25 percent of the orange acreage was fertilized.

Source: (49).

Although coffee is listed as the largest consumer of fertilizer, less than one-fifth of its area is fertilized. Cotton and corn are heavy users of fertilizer in the United States, but in Sao Paulo,only 48 percent and 12 percent, respectively, of their area was fertilized in 1969.

Affect on Crop Yields

If it is assumed that all crops received little or no fertilizer during the early 1950's, then the proportion of crop area fertilized in 1969 would indicate the approximate increase in fertilizer use since the early 1950's. If increased use was related to an increase in crop yields, a close relationship between a rapid rate of yield increase and a high proportion of crop area fertilized would be expected. According to these criteria, four of the relationships listed--for coffee, oranges, sugarcane, and rice -- contradict expectation of more rapid rates of yield increase due to the use of fertilizers. However, an examination of the area trends outlined earlier (pages 9-16) provides some possible explanations for these deviations.

Area planted to coffee declined by approximately one-half, with older, lower yielding trees the ones eliminated. Orange and sugarcane area expanded greatly, possibly moving into less desirable production areas. Rice production shifted to less fertile soil areas. Thus, despite these contradictory cases, there apparently was some relationship between improvements in yields and fertilizer use in Sao Paulo:

Crop	Average annual yield increase, 1950-54 to 1967-71	Crop area fertilized, 1969
	Percent	
Bananas	5.1	38
Cotton	5.1	48
Potatoes	1/4.3	100
Coffee	3.4	18
Tomatoes	2.9	100
Corn	1.6	12
Oranges	1.4	100
Sugarcane	0.8	100
Peanuts	0.6	4
Rice	-2.2	32

1/ 1950-54 to 1966-70.

Source: Calculated from (74, 49).

In demonstration plot tests between 1969 and 1973 in the States of Minas Gerais and Goias, the use of fertilizer was found to have a significant impact on yields. The average percentage increases in yields with use of fertilizer compared with control plots are shown in the following tabulation:

Commodity	State	
	Minas Gerais	Goias
	Percent	
Corn	102	75
Dryland rice	101	104
Beans	108	151

Source: (71).

The average value/cost ratios (increased value of product harvested relative to cost of fertilizer) ranged from 2.3 to 4.0 (71).

Contradictory results on crop response to fertilizer use in Sao Paulo were shown in a recent study by Nelson and Meyer (54). They surveyed 174 farms in the Ribeirao Preto area of Sao Paulo in the 1969/70 crop year and concluded that the marginal income from fertilizer use on corn, rice, cotton, and soybeans was generally negative. Farmers not using fertilizer obtained yields as good as those who did.

However, response to fertilizer tended to be higher for the group of farmers using larger amounts of fertilizer. The authors hypothesized that the poor fertilizer response they discovered could be due to problems peculiar to terra roxa soils, a combination of nutrients inadequate for correcting soil deficiencies, improper application of fertilizers, plant varieties not responsive to fertilizers, or the application of insufficient amounts of fertilizers.

Imports and Production

In 1973, 70 percent of Brazil's fertilizer needs were supplied by imports, down from 78 percent in 1972 when the cost of fertilizer imports reached $157 million.

The following tabulation shows that the share of the Brazilian fertilizer market supplied by Brazilian manufacturers declined from 1964 to 1970 but increased somewhat after that:

Year	Percent	Year	Percent
1959	44	1966	32
1960	35	1967	26
1961	39	1968	22
1962	41	1969	21
1963	35	1970	19
1964	42	1971	28
1965	34	1972	22
		1973	30

Sources: (111, July, 1971; 48; 112, July-August, 1972; 119, 1973/74).

In 1973, Brazilian suppliers produced 39 percent of Brazil's nitrogen needs, 46 percent of its phosphate, and none of its potassium. In 1969, Brazilian producers supplied only 3 percent of their country's nitrogen fertilizer needs (112, July-August, 1972; 119, 1973/74). Also, Brazilian supplies of limestone are plentiful (2, p. 297).

Outlook

According to Sao Paulo's Agricultural Economics Institute, the majority of the State's farmers have long been aware of the agronomic advantage of fertilizer use (74, p. 129; 73, p. 35), and a recent survey in northern Sao Paulo revealed that practically all the farmers in the area surveyed use fertilizer (53, note 1, p. 3). However, the potential for increasing the amount and efficiency of fertilizer use in Sao Paulo is still great. As of 1969, much of the area in crops thought to be responsive to fertilization, like coffee, cotton, and corn, remained unfertilized. Nelson's 1970 survey of farmers revealed that many farmers were not using a complete fertilizer package. Only 45 percent of the farmers surveyed had their soil analyzed, and only 60 percent had ever used lime (53, note 1, p. 3).

Most areas of Brazil have a long way to go before they attain Sao Paulo's level of fertilizer use. In the Northeast, only sugar receives a large amount of fertilizer. In the Central region, outside of Sao Paulo, fertilizer is used on a wide range of commodities, but the amount of cropland receiving fertilizers is much less than in Sao Paulo. In the extreme South, the large commercial wheat-soybean farmers are heavy users of fertilizer, but much potential for increased use remains among irrigated rice growers and the small-scale farmers of northern Rio Grande do Sul and Santa Caterina.

Improved Seeds 37/

The use of improved seeds has been an important factor behind recent increases in crop yields in southern Brazil. Continued expansion of their use, development of better varieties, and the increased use of inputs complementary to improved seeds should lead to further improvements in crop yields. The following tabulation shows estimates of the percentage of cropland seeded with improved seeds in southern and southeastern Brazil in 1967 and 1971:

Commodity	1967	1971
	Percent	
Wheat	28	89
Cotton	69	77
Soybeans	69	66
Corn	19	22
Potatoes	12	20
Rice	5	12
Peanuts	4	7
Beans	--	3

-- = less than 0.5.

Source: Brazil Ministry of Agriculture.

Federal Government planners anticipate a significant increase in the use of improved seeds by the mid-1970's. A National Seed Plan has been instituted to coordinate research into new varieties, seed production, and multiplication in cooperation with private producers (112, Nov.-Dec., 1971).

In Sao Paulo, cotton yields increased faster than yields for all other major crops, in part due to improved seed varieties. A program with heavy emphasis on cotton research at the State's institute of agricultural research (Instituto Agronomico de Campinas) was started in 1924. The program concentrated on developing new varieties with better yields, higher fiber content, and longer fiber length.

37/ Seeds for planting which have been selected for their superior genetic qualities and which have been improved by such means as drying, washing, and disinfecting.

These varieties were marketed through a State seed monopoly which insured that all cotton planted in Sao Paulo was of the improved varieties. An intensive program to improve cultivation practices was associated with distribution of the seeds (6, pp. 557-558; 119, 1974/75; 76, pp. 165, 168, 176). Presently, all of the cotton planted in Sao Paulo is improved seed.

Hybrid corn seed is more extensively used in Sao Paulo than in any other Brazilian State. The IEA estimated that 77 percent of the corn planted in Sao Paulo in 1973 was improved seed (mostly hybrid), compared with 42 percent in 1963 (69, 1974/75).

Although corn yields have been rising in Sao Paulo, they are not close to the yield potential of the hybrid varieties being used. This is due mainly to the lack of proper fertilization and the poor agricultural practices which result in low plant densities per hectare (76, p. 168; 39, p. 7). One estimate indicates that only 12 percent of Sao Paulo's corn area was fertilized in 1969 (page 55). The practice of fertilizing corn is increasing rapidly, however (80). In Sao Paulo and neighboring areas, good hybrid corn varieties with adequate fertilizer applications and appropriate cultural practices produce up to twice as much as common varieties, while hybrid corn without fertilizer produces only 20 to 30 percent more than common varieties. (TOAID 282, Rio de Janeiro, March 29, 1969).

Relatively little progress has been made in the adoption of improved seeds for other crops such as rice or peanuts. Most Brazilian research on rice varieties is concentrated in the irrigated producing region of Rio Grande do Sul. However, Sao Paulo's Instituto Agronomico is doing research on crosses with IR-8 and other short straw rice varieties (124, June 18, 1972).

Pesticides

Use of agricultural pesticides in Brazil apparently doubled between 1960 and 1970 and has continued to increase in recent years. Estimates of Brazilian pesticide consumption are as follows:

Pesticides	1969	1973
	Metric tons	
Insecticides	33,514	33,844
Fungicides	5,685	32,382
Herbicides	1,451	8,381
Total	40,630	74,607

Source: Sindicato da Industria de Defensivos do Estado de Sao Paulo in (119, 1974/75).

The actual use of insecticides has increased more than the tabulation indicates because in recent years a more concentrated product has been used. The increasing use of fungicides is due principally to their role in treating coffee rust (Hemileia vastatrix). Increased herbicide use has been due in part to a relative scarcity of labor in some areas (119, 1974/75). There are no available data on the use of pesticides in Sao Paulo. Pesticides are used mainly in Sao Paulo for controlling

insect pests on cotton, potatoes, and tomatoes and for treating seeds against insect pests before planting. Also, formicides (for control of ants) and fumigants are commonly used to destroy pests in the soil before planting (74, pp. 136-137).

Most of the insecticides consumed in Sao Paulo are used on cotton--in 1966, cotton took approximately three-quarters of the total. The chemicals are applied directly to the plant by hand and tractor equipment. During years of severe insect attack, some farmers may make as many as 12 applications (69, p. 12). Also, cotton seeds distributed by the Sao Paulo Secretariat of Agriculture are treated with insecticides before sale (76, p. 168). Herbicides are used mainly on sugarcane (119, 1974/75).

Pesticides are rarely used on corn in Brazil, and then only when major outbreaks of pests such as army worms or grasshoppers occur (80). A 1967 survey in a major rice-producing region of Sao Paulo found that 25 out of 53 farmers (on 61 percent of the cultivated land) used pesticides, mostly for treating seeds prior to planting. In some cases, the soil was also treated to kill ants (47).

In recent years, pesticide prices in Sao Paulo have risen at approximately the same rate as the general price index (74, p. 86). This trend differs from the fertilizer situation where, until recently, prices tended to rise less rapidly than the general price level (page 49).

CONCLUSIONS

The following conclusions can be drawn concerning crop production in Sao Paulo: (1) Sao Paulo farmers have led the country in the adoption of "modern" agricultural techniques; (2) agricultural development in Brazil has been concentrated in relatively few areas; and (3) there is apparently a large potential for further improvements in crop yields and labor productivity in Sao Paulo as well as in the less developed parts of Brazil.

In this brief study, it is not possible to determine the factors responsible for Sao Paulo's more rapid agricultural development and leadership in the adoption of "modern" agricultural techniques. However, some hypotheses can be presented. Some of the credit must go to the State's excellent endowments, but many other factors, such as cultural traditions, educational levels of the farm population, research and extension systems, infrastructure, and the use of agricultural credit, have doubtlessly contributed.

Within Brazil, the residents of Sao Paulo are recognized for their dynamic and enterprising nature. A recent U.S. study notes that the typical Sao Paulo resident values hard work, production, and profits (83, p. 257). The history of the settlement and growth of Sao Paulo reveals some of the special qualities of its people. The first Europeans who settled in the area were not wealthy but were apparently a vigorous, energetic, and adventurous people. The descendents of those first Paulistas became known as bandeirantes, an exceptionally bold and audacious people. In their search for Indian slaves in the interior they explored and settled most of what is now Brazil (40, p. 480; 32 pp. 60-61).

The rapid expansion of coffee production in Sao Paulo in the latter part of the nineteenth century transformed the State from a backwater cattle-raising area to one of the wealthiest and most dynamic areas of the country. One of the consequences of the expansion of coffee cultivation and the accompanying growth was a demand for labor which made Sao Paulo the principal attraction for immigration

into and within Brazil. Between 1886 and 1936, 2.8 million foreign immigrants entered Brazil, of which 60 percent went to Sao Paulo. About two-thirds of the immigrants entering Sao Paulo were Italians. Other important nationalities were Portuguese, Spaniards, and Japanese (32, p. 140; 78, pp. 120-136; 40, pp. 448-85). Preston James points out other characteristics of Sao Paulo farmers which may have been factors in their relative success.

> "The fazenda paulista...is by no means a social unit, as was the old sugar estate of the Northeast. It is essentially a business enterprise...for the sake of profit. The objective of both fazendeiro and tenant is more wealth... The owner himself commonly moves to his new estate...The fazendeiros of Sao Paulo...are closely in touch with the business of producing coffee; they are not...interested primarily in pastoral life and willing to leave farming to the tenants...Although in Sao Paulo State there are longer hours of work than in Minas, and the laborers are expected to work harder..., the wages are higher." (40, pp. 486-487)

The educational levels of Sao Paulo farmers are higher than in most other areas of Brazil. In 1970, 62 percent of the economically active population in Sao Paulo's agricultural sector had some formal instruction, compared with only 42 percent for all of Brazil (table 28). Only in the southern States of Santa Caterina and Rio Grande do Sul were educational levels higher.

Agricultural research and extension systems are apparently better developed in Sao Paulo than in other parts of Brazil. Agricultural research organizations connected with the State Secretariat of Agriculture include The Institute Agronomico de Campinas, which is recognized as one of the best such organizations in the country. In 1969, the State Secretariat of Agriculture employed 720 technicians in agricultural research, compared with 850 employed by Brazil's Federal Ministry of Agriculture. Private firms in Sao Paulo also employ many research technicians.

Table 28--Educational levels of the economically active population 10 years of age and over in the agricultural sector of Brazil, 1970

Region	Amount of formal education		
	Some	More than 2 years	More than 5 years
	Percent		
Brazil	42	20	1
Sao Paulo	62	38	3
Southeast (less Sao Paulo)	48	22	1
Parana	55	26	1
Estreme South 1/	75	52	1
Rest of Brazil 2/	26	8	1

1/ Santa Catarina and Rio Grande do Sul.
2/ North, Northeast, and Center-West.

Source: (23).

Sao Paulo is the only Brazilian State not associated with ABCAR (Associacao Brasileira de Credito e Assistencia Rural), the national agricultural extension system. (In 1971, the ABCAR system employed 3,015 professionals working out of 1,270 offices throughout Brazil. However, Sao Paulo has its own technical assistance organization which in 1969 employed 740 professionals in 573 local offices--Casas de Agricultura). The Sao Paulo extension system is more closely integrated with agricultural research organizations than is the ABCAR system. In addition to government assistance, Sao Paulo farmers received technical assistance from 444 technicians from the private and cooperative sectors in 1969 (63, p. 105, 123, 125; 76, pp. 234, 250; 37, p. 90).

Sao Paulo's economic infrastructure, in particular its transportation system, is more developed than in the rest of Brazil. In 1970, 14.7 percent of Brazil's highway mileage was in Sao Paulo, which covers less than 3 percent of the country's area. Nine percent of Sao Paulo's highways were paved, compared with 5 percent for all of Brazil. In 1971, Sao Paulo's share of Brazil's railroad milage was 18 percent (93).

Agricultural credit is used more in Sao Paulo than in the rest of Brazil. In 1970, agricultural loans were made at the rate of 1 per 0.9 farms, compared with 1 loan for every 4.1 farms in Brazil as a whole. The following tabulation shows some indicators of the importance of this credit in 1970:

Item	Sao Paulo	Brazil
	Cruzeiros	
Average size of loan	8,805	7,768
Amount loaned per person employed	2,092	509
Amount loaned per farm 1/	9,424	1,879

1/ Counts total number of farms, not just those which received loans.

Sources: (24; 63, p. 136).

Recent developments in Brazil indicate that many of the economic advantages enjoyed by Sao Paulo may be spreading to the rest of Brazil, especially to the other Center-South States. Thus, the gap between Sao Paulo and the other States may be narrowing. Rural primary education, for example, is expanding throughout Brazil. Rural primary school enrollment in Brazil grew from 3 million in 1960 to 4.7 million in 1970, or from 8 to 12 percent of the total rural population. In Sao Paulo, the numbers enrolled in rural primary schools declined during the 1960's, but enrollment as a percentage of total rural population increased from 10 to 12 percent (93; 23).

Governmental actions are also furthering the spread of economic advantages throughout the country. Agricultural research institutions in Brazil are being strengthened by the recent creation of EMBRAPA, the Brazilian agricultural Research Enterprise 38/. Under the new enterprise, all Federal agricultural research organizations will be freed of the bureaucreatic problems which have hindered the Federal

38/ Empresa Brasileira de Pesquisa Agropecuaria.

agricultural research establishment in the past (63). Current Government programs are also expanding and improving the highway and railroad systems throughout the country.

Finally Sao Paulo's cultural traditions are also being transferred to the rest of the country by the emigration of Sao Paulo farmers to Parana, Mato Grosso, Goias, Minas Gerais, and the Amazon Basin.

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Appendix table 1--Area planted to principal crops, Sao Paulo, 1950-74 1/

Crop	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
	1,000 hectares											
Sugarcane	159	186	223	254	301	286	234	380	414	429	410	471
Coffee	1,287	1,317	1,393	1,443	1,645	1,687	1,651	1,575	1,584	1,552	1,478	1,386
Oranges	11	16	16	21	26	33	38	46	60	67	81	75
Bananas	44	41	54	60	69	76	80	79	75	78	60	52
Grapes	5	5	5	5	6	7	7	7	11	13	13	15
Corn	847	747	744	832	1,234	1,246	997	1,113	1,150	954	1,324	1,186
Cotton	1,181	1,162	1,332	967	789	629	786	474	411	484	498	569
Rice	600	495	391	530	508	629	581	460	547	595	574	644
Peanuts	125	174	106	137	182	176	120	146	241	249	295	427
Soybeans	1	1	1	2	6	7	5	5	4	3	4	6
Beans	201	191	156	239	313	278	238	315	360	261	448	356
Manioc	71	42	36	43	59	62	60	70	104	101	94	98
Caster beans	45	26	53	45	37	29	24	37	46	39	34	50
Wheat	1	3	3	5	4	3	3	5	8	8	7	5
Potatoes	37	48	48	43	49	47	45	43	44	43	47	44
Tomatoes	9	9	5	6	9	8	6	6	8	8	7	9
Onions	8	5	7	9	10	9	11	9	9	9	9	10
Total perennial crops 2/	1,486	1,565	1,691	1,783	2,047	2,089	2,064	2,087	2,144	2,139	2,040	2,019
Total annual crops	3,146	2,903	2,882	2,858	3,200	3,123	2,822	2,683	2,932	2,754	3,343	3,404
All crops	4,632	4,468	4,573	4,641	5,247	5,212	4,886	4,770	5,076	4,893	5,383	5,423
Second crops 3/	4/145	159	4/118	192	264	206	166	236	313	268	4/388	355
Adjusted total, all crops 5/	4,487	4,309	4,455	4,449	4,983	5,006	4,720	4,534	4,763	4,625	4,995	5,068

See footnotes at end of table.

Continued

Appendix table 1--Area planted to principal crops, Sao Paulo, 1950-74 1/--Continued

Crop	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 6/
	1,000 hectares												
Sugarcane	489	516	569	695	688	652	627	634	758	823	819	802	870
Coffee	1,203	999	806	763	743	708	684	684	681	694	694	734	800
Oranges	101	111	113	124	103	112	121	156	189	213	251	305	378
Bananas	36	34	40	44	36	36	38	29	25	26	4/24	31	4/30
Grapes	15	16	11	10	9	9	9	9	10	13	4/12	4/12	4/12
Corn	1,331	1,573	1,263	1,396	1,367	1,476	1,573	1,246	1,476	1,694	1,500	1,300	1,290
Cotton	678	605	508	653	477	290	339	448	702	605	630	430	396
Rice	508	762	1,108	1,065	702	753	881	774	636	557	503	519	465
Peanuts	479	382	409	414	482	552	390	469	448	506	504	270	210
Soybeans	7	5	4	7	14	23	28	48	67	87	127	200	335
Beans	358	387	386	330	322	370	225	235	285	259	250	270	290
Manioc	113	172	147	135	120	116	129	131	105	94	96	105	87
Castor beans	58	62	63	65	67	53	76	80	64	55	4/70	74	128
Wheat	9	9	7	4	7	8	5	10	8	23	27	29	95
Potatoes	39	39	40	34	29	35	34	34	36	35	37	34	34
Tomatoes	9	21	15	10	13	13	19	18	20	24	4/22	21	29
Onions	8	8	8	9	9	10	9	12	13	12	4/13	4/12	11
Total perennial crops 2/	1,844	1,676	1,539	1,636	1,579	1,517	1,479	1,512	1,663	1,769	1,794	1,885	2,090
Total annual crops	3,597	4,025	3,958	4,122	3,609	3,699	3,708	3,505	3,860	3,952	3,785	3,261	3,370
All crops	5,441	5,701	5,497	5,758	5,188	5,216	5,187	5,017	5,523	5,721	5,579	5,146	5,460
Second crops 3/	4/389	327	359	362	377	4/437	4/272	358	333	4/360	4/349	245	211
Adjusted total, all crops 5/	5,052	5,374	5,138	5,396	4,811	4,779	4,615	4,659	5,190	5,361	5,230	4,901	5,249

1/ Year of harvest, except wheat, which refers to the crop harvest late in the year preceeding that indicated.
2/ Sugarcane, coffee, oranges, bananas, and grapes.
3/ Land planted for the second annual harvest of peanuts, beans, and potatoes.
4/ Authors' estimate.
5/ Estimates of total cropland and of total annual cropland are overstated because land which is double cropped is counted twice--once for each harvest. The "adjusted total" subtracts the cropland used for the second crop of peanuts, beans, and potatoes from the cropland total.
6/ Preliminary.

Source: (74, 119), for all commodities except grapes and wheat. Wheat, 1950-60, and the grape series are from (93). Wheat, 1961-71, is from (88 p. 57).

Appendix table 2--Production of selected crops, Sao Paulo, 1950-74

Year 1/	Sugar-cane	Coffee	Oranges	Corn	Cotton lint 2/	Rice	Peanuts	Soybeans	Beans
				1,000 metric tons					
1950	6,993	453	138	1,227	148	901	131	1	125
1951	8,436	444	115	1,076	202	763	194	1	122
1952	9,927	487	98	1,005	318	534	132	1	102
1953	10,865	482	157	992	216	543	126	2	148
1954	12,686	564	199	1,458	196	558	191	6	121
1955	12,230	648	252	1,080	207	684	223	8	88
1956	14,751	456	314	1,029	171	449	122	4	102
1957	16,750	666	392	1,338	118	528	180	6	150
1958	19,562	678	501	1,380	130	540	339	4	150
1959	22,174	954	591	1,332	166	648	364	3	116
1960	21,704	498	722	1,740	174	660	362	4	196
1961	23,152	678	936	1,764	172	792	465	7	139
1962	26,600	312	960	2,214	235	612	545	8	116
1963	22,000	606	1,080	2,688	197	720	480	5	161
1964	25,100	108	815	1,416	197	900	382	4	148
1965	39,092	702	1,168	2,448	172	1,026	600	11	189
1966	38,899	372	1,161	2,490	231	576	668	22	150
1967	33,500	510	1,376	2,640	135	900	491	37	162
1968	30,225	276	1,422	2,550	149	636	538	37	117
1969	27,400	378	1,393	1,740	198	546	532	60	79
1970	42,500	258	1,774	2,820	233	780	620	98	140
1971	38,300	648	1,840	2,760	220	348	638	94	138
1972	44,200	540	2,428	3,000	218	660	645	222	123
1973	42,000	420	2,840	2,598	205	582	312	330	134
1974	41,460	587	3,280	2,628	168	582	267	522	131

1/ Year of harvest.
2/ Seed cotton converted to lint at a rate of 0.33.

Sources: (74, 119).

Appendix table 3--Prices received by farmers for selected commodities, Sao Paulo, 1950-73

Year	Sugar-cane	Coffee	Oranges	Corn	Seed cotton	Rice	Peanuts	Soybeans	Beans	Beef
	Constant 1969 cruzeiros per metric ton 1/									
1950	22	3,187	96	166	802	325	424	392	342	1,111
1951	19	2,576	110	195	1,141	263	376	384	376	1,212
1952	19	2,387	157	252	770	462	335	387	462	1,378
1953	17	2,588	121	263	622	753	395	386	667	1,373
1954	19	3,395	123	170	654	585	419	341	332	1,278
1955	19	2,817	155	280	720	491	305	351	722	1,444
1956	23	2,533	137	250	653	554	379	331	781	1,320
1957	21	2,287	112	216	686	551	465	368	639	1,124
1958	17	1,470	117	234	663	604	330	344	382	1,121
1959	17	1,200	88	254	624	479	327	326	976	1,244
1960	19	1,248	71	174	751	407	504	405	886	1,733
1961	18	1,255	61	253	827	362	438	376	531	1,828
1962	20	1,435	87	231	690	675	359	399	1,203	1,836
1963	27	1,652	82	169	634	697	335	362	743	1,663
1964	29	2,166	144	219	693	456	622	380	503	1,465
1965	26	1,328	86	168	667	275	442	354	459	1,498
1966	20	972	72	178	548	479	412	415	817	2,084
1967	19	1,015	64	156	520	466	291	307	468	1,680
1968	18	1,208	82	126	560	379	386	335	471	1,495
1969	18	1,693	95	184	541	302	373	341	936	1,406
1970	17	2,025	95	157	526	416	346	353	657	1,705
1971	17	1,559	109	165	658	483	424	370	670	1,987
1972	17	2,111	93	166	675	472	363	360	732	2,101
1973	18	2,491	116	232	808	455	526	498	1,684	2,749

NA=not available.

1/ Prices deflated by Getulio Vargus Foundation Index no. 2. Average exchange rate in 1969 was Cr $4.14=U.S. $1.00.

Sources: (74, 119).